Integrating climate change adaptation into biodiversity and forestry assessments and programming

Byers, Bruce; Cameron, Alison

DOI:
10.13140/RG.2.2.34737.74083

Published: 01/06/2013

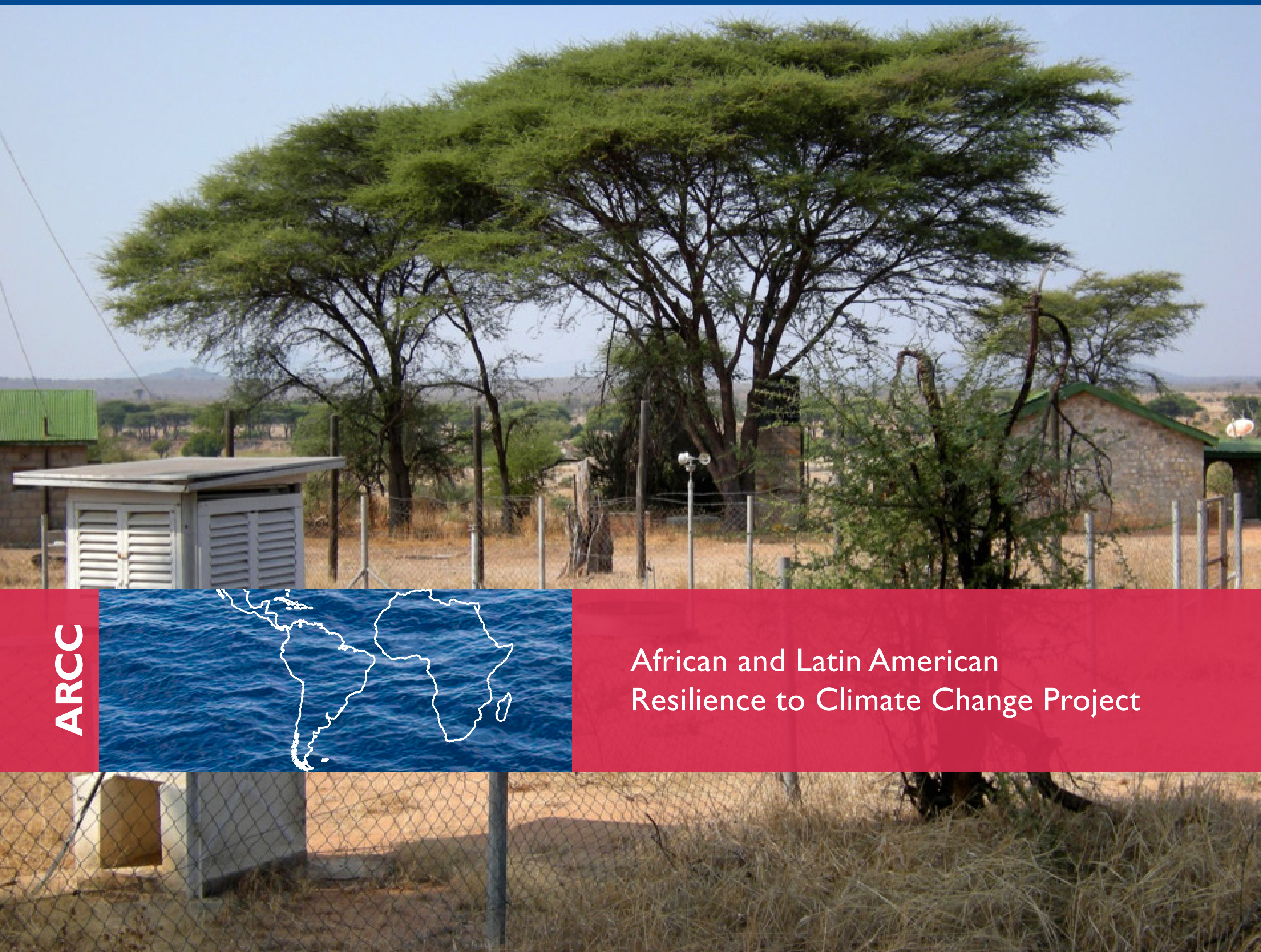
USAID
FROM THE AMERICAN PEOPLE

BACKGROUND PAPER ON

INTEGRATING CLIMATE CHANGE ADAPTATION INTO BIODIVERSITY AND FORESTRY ASSESSMENTS AND PROGRAMMING

June 2013

This publication was produced for review by the United States Agency for International Development.



ARCC

African and Latin American Resilience to Climate Change Project

PREPARED BY

This report was produced for review by USAID. It was prepared by consultants Dr. Bruce Byers and Dr. Alison Cameron under contract to the USAID African and Latin American Resilience to Climate Change (ARCC) Project. ARCC is a USAID/Washington D.C.-based PLACE IQC Task Order, implemented by Tetra Tech, which provides technical services to bring improved climate change adaptation science, methodologies and tools, and shared learning into the mainstream of USAID and development partner programming.

Dr. Bruce Byers: (Independent Consultant) Biodiversity/Forestry/Climate Change Specialist and Team Leader

Dr. Alison Cameron: (Independent Consultant) Climate Change and Biodiversity Scientist

ARCC Supervisor: Dr. Matt Sommerville

Cover photo: Weather station at the headquarters of Ruaha National Park, Tanzania. Photo by B. Byers, June 2012.

June 2013

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

ABCG	Africa Biodiversity Collaborative Group
AOGCM	Atmosphere-Ocean General Circulation Models
ARCC	African and Latin American Resilience to Climate Change
ASCII	American Standard Code for Information Interchange
CBD	Convention on Biological Diversity
CCD	Climate Change and Development
CDCS	Country Development Cooperation Strategy
CO_2	Carbon Dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organization
ELAN	Ecosystems and Livelihoods Adaptation Network
EPA	Environmental Protection Agency
ESRI	Economic and Social Research Institute
ETOA	Environmental Threats and Opportunities Assessment
FAA	Foreign Assistance Act
FAO	Food and Agriculture Organization of the United Nation
GCM	General Circulation Model
GIZ	German Agency for International Cooperation
IEG	Independent Evaluation Group of the World Bank
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
NAP	National Adaptation Plan
NAPA	National Adaptation Program of Action
NCAR	National Center for Atmospheric Research
NGO	Nongovernmental Organization
RCM	Regional Climate Models
SBSTA	Subsidiary Body for Scientific and Technological Advice

SDM	Species Distribution Model
SES	Social-Ecological System
SOW	Scope of Work
TNC	The Nature Conservancy
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USG	United States Government
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund

ACKNOWLEDGEMENTS

We wish to thank Tegan Blaine, Jonathan Cook, other anonymous reviewers from USAID, and Matt Sommerville (Technical Advisor for this task from Tetra Tech), for their constructive comments on an earlier draft of this report.

EXECUTIVE SUMMARY

BACKGROUND

The main objectives of this study are to provide recommendations about how the actions needed to conserve biodiversity and adapt to climate change can be better integrated, and thereby lead to mutually-beneficial synergies that will create more effective programming. The study team reviewed relevant literature, compared assessment methodologies of a range of conservation and development organizations, and reviewed recent U.S. Agency for International Development (USAID) Biodiversity and Tropical Forestry and Environmental Threats and Opportunities Assessments.

The relationship between climate change adaptation and biodiversity conservation goes in two directions: biodiversity might be threatened by climate change, and conserving biodiversity might help societies adapt to the effects of climate change. We found general consensus that assessments and programming need to address the following items:

- Climate change adaptation for biodiversity conservation
- Biodiversity conservation for societal adaptation to climate change
- Avoiding harm to biodiversity from adaptation actions

USAID's policies and guidance generally describe both climate change adaptation and biodiversity conservation as cross-cutting, cross-sectoral issues and needs. We found, however, that in practice these topics are sometimes treated as "sectors" for programming. We compared 15 recent climate change assessment methodologies, frameworks, or guidelines from a representative range of governmental and nongovernmental organizations on some key dimensions related to the integration of climate change adaptation and biodiversity conservation. We found several good examples of conceptual frameworks for integrating climate change adaptation and biodiversity conservation that can serve as models for further development and testing of an integrated approach.

ADAPTATION FOR CONSERVATION

The development of adaptation strategies for biodiversity conservation starts with an assessment of the effects of predicted climate changes on species and ecosystems. Options for adjusting conservation strategies and actions to address these vulnerabilities can then be identified. We found many assessment frameworks designed to carry out these two steps that have been developed by conservation organizations and agencies within the last decade. Climate change is expected to affect biodiversity at all levels – ecosystems, species, and genetic variation within species. Many of the frameworks for conservation for adaptation provide checklists of options for adjusting conservation strategies to the threat of climate change.

CONSERVATION FOR ADAPTATION

Conserving biodiversity as an approach to climate change adaptation first requires an assessment of how the benefits that biodiversity provides to human societies might be affected by predicted climate changes; and, second, the identification of options for maintaining those benefits as a significant component of climate change adaptation strategies. We found several examples of conceptual frameworks that take this approach in our review of the literature. Two concepts that are gaining attention – ***ecosystem-based approaches to adaptation*** and ***resilience*** – are especially relevant to conservation for adaptation.

Ecosystem-based approaches to adaptation make use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Ecosystem services are the benefits to humans that result from ecosystem functions and processes, such as clean and stable flows of water (hydrological services), carbon sequestration and climate regulation, pollination, and nutrient cycling. These result from biodiverse ecosystems, so biodiversity conservation is a fundamental requirement for conserving ecosystem services and for ecosystem-based adaptation. Resilience is the capacity of a system to absorb disturbance and reorganize but still retain essentially the same function and structure. The concept of ecological resilience, like that of ecosystem services, is key to integrating climate change adaptation and biodiversity conservation. Many empirical and theoretical studies show that greater species-level biodiversity makes ecosystems more resilient.

AVOIDING THREATS TO BIODIVERSITY FROM ADAPTATION ACTIONS

The need to be aware of potential effects on biodiversity from climate change adaptation measures taken in other sectors (e.g., effects of "hard" infrastructure like seawalls and levies, dams for irrigation and/or flood control, or promotion of irrigated agriculture) has been recognized for at least a decade. A major intent of Congress in enacting the Foreign Assistance Act Section 118 and 119 requirements for Tropical Forestry and Biodiversity analyses was to avoid harm to biodiversity from USAID-funded development assistance. These assessments are one tool that can help USAID avoid maladaption from proposed climate change adaptation activities.

CONCLUSIONS

- Creating synergies between biodiversity conservation and resilience to climate change requires that assessments for each incorporate elements of the other, and that project and program design take the information from each kind of assessment into consideration.
- Conservation scientists and organizations have developed frameworks and methods that can adequately assess the vulnerability of biodiversity to climate change for conservation planning purposes.
- Good examples of conceptual frameworks for integrating climate change adaptation and biodiversity conservation that can provide models for further development already exist.

- USAID Tropical Forestry and Biodiversity Assessments do not yet incorporate the concepts of resilience and ecosystem-based approaches to adaptation effectively.
- Many USAID-funded biodiversity projects show "triple co-benefits" for biodiversity, climate change adaptation, and climate change mitigation.

RECOMMENDATIONS

International and national government agencies and non-governmental organizations involved in biodiversity conservation and sustainable development should:

1. Disseminate, test, refine, and promote the already well-developed concepts of adapting biodiversity conservation strategies to take climate change into account.

2. Continue to develop the view that biodiversity is the foundation for sustainable human development and of resilience of social-ecological systems to climate change, rather than viewing biodiversity conservation as a special interest or "sector;"

3. Further develop, and expand the use of, relatively new assessment frameworks and methodologies that integrate climate change adaptation and biodiversity conservation as cross-cutting issues, and lead toward integrated programming that views ecosystem-based approaches to climate change adaptation as a critical component of all adaptation strategies; and

4. Develop appropriate information and practical guidance to introduce, define, and promote key terms and concepts within their organizations, including: ecosystem services, ecosystem-based approaches to adaptation, social-ecological systems (SESs), and resilience in SESs.

USAID should:

1. Develop updated guidelines for FAA 118-119 analyses and Environmental Threats and Opportunities Assessments (ETOAs) that calls attention to the best available information, frameworks, and methodologies for "adaptation for conservation," "conservation for adaptation," and encourages awareness of the need to "do no harm" to biodiversity through interventions proposed in the name of climate change adaptation.

2. Develop guidelines for USAID staff and consultants conducting climate change vulnerability assessments and developing adaptation options that makes them aware of the same three topics, above, needed in biodiversity assessments. Climate change vulnerability assessments and options analyses should address the issue of ecosystem-based adaptation options, and consider the topics of ecosystem services and resilience of social-ecological systems.

3. Revise and strengthen its 2012 document entitled, ***Building Resilience to Recurrent Crisis,*** by incorporating the well-developed use of the concept of resilience in social-ecological systems. The key roles of biodiversity, ecosystems, and ecosystem services in maintaining the resilience of social-ecological systems in the face of climate change should be emphasized.

1.0 INTRODUCTION

1.1 OBJECTIVES OF THIS STUDY

The main objectives of this study are to provide recommendations about how the actions needed to conserve biodiversity and adapt to climate change can be better integrated, and thereby lead to mutually-beneficial synergies that will create more effective programming. The study explores the role of assessments of threats to biodiversity and of climate change vulnerability in program development.

According to our scope of work (SOW), "The target audience for this work is development practitioners who assess threats to biodiversity and forestry and develop and implement associated activities. Specific advice will be targeted to USAID and its partners."

This study was conducted by a two-person team with expertise in international biodiversity conservation policy and practice and climate change modeling and biodiversity conservation (see Annex C). The study team reviewed relevant literature (see Annex A), critically compared assessment methodologies of a range of conservation and development organizations to analyze the extent to which they integrated concepts of biodiversity conservation and climate change adaptation (see Annex D), and reviewed recent USAID Biodiversity and Tropical Forestry assessments and ETOAs from Africa and Latin America (see Annex E).

1.2 BACKGROUND ANALYSIS

The relationship between climate change adaptation and biodiversity conservation goes in two directions: biodiversity may be threatened by climate change, and conserving biodiversity may help societies adapt to the effects of climate change. The Convention on Biological Diversity (CBD), for example, recognizes these two interactions, saying that there is "firstly the need to adopt adaptation strategies and practices to maintain biodiversity itself in the face of climate change," and also to recognize "…the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse impacts of climate change." In addition to these needs, the CBD also proposes another issue, "… the potential impacts of broader adaptation activities on biodiversity" (CBD, 2009a, p. 31). These three types of interactions could be referred to as:

- climate change adaptation for biodiversity conservation;
- biodiversity conservation for societal adaptation; and
- avoiding harm to biodiversity from adaptation actions.

Organizations with interests in either biodiversity or climate change will have an interest in one of more of these three issues, but may place more emphasis on one or another depending on the organization's mission. For example, biodiversity conservation organizations may focus mainly on the need for adaptive measures to conserve biodiversity, whereas the main interest of development organizations may be the need to conserve biodiversity as part of an overall strategy for societal adaptation to climate change. These different interests are reflected in both the assessment methodologies and in the strategies and programs of different kinds of organizations. In Section 1.3 we summarize our analysis of the assessment methodologies of a range of organizations to illustrate this point.

Through a literature review, we found that a fair degree of consensus exists among international development scholars and practitioners that approaches to climate change adaptation that integrate biodiversity conservation are needed for maximum effectiveness. Consider the following two statements as examples, one from an international conservation organization, Conservation International, and one from a bilateral development agency, the German Agency for International Cooperation (GIZ):

- "Adaptation traverses many sectors and requires holistic solutions. An integrated approach to adaptation should include and consider ecosystems, the services they provide, indigenous and local knowledge, and community needs and capacities comprehensively" (Conservation International, 2012b, p. 2).
- "At all levels, biodiversity is connected to climate change adaptation. Addressing the links between biodiversity and climate change adaptation and using synergies is critical if we are to achieve sustainable development and meet the objectives of the Rio Conventions. For people in developing countries, in particular, biological diversity and ecosystem services are a question not only of future adaptability but a key contribution to livelihoods" (GIZ, 2011, p. 26).

Despite this general consensus on the need to better integrate biodiversity conservation and climate change adaptation – and high-level expressions of the aspiration to do so – practical, on-the-ground attempts to integrate them are quite recent. So far, practical experience is so limited that it is hard to point to a body of evidence that proves that their integration leads to more effective outcomes. Careful monitoring and evaluation will be needed to provide such evidence.

To support ***climate change adaptation for biodiversity conservation***, what is needed is a conceptual framework that identifies the effects of predicted climate changes on biodiversity, and develops options and strategies that help to maintain the resilience of ecosystems and species. This topic is discussed in more detail in Section 3 of this report. It is important to keep in mind that climate change is only one of five main categories of direct, biophysical threats to biodiversity recognized by conservation biologists: (IUCN, 2011; CBD, 2006, p. 32; USAID, 2005a):

- Conversion, loss, degradation, and fragmentation of natural habitats
- Overharvesting or overexploitation of particular species
- Invasive non-native species that harm native ecosystems or species
- Pollution or contamination that harms natural habitats or species
- Climate change effects that harm natural habitats or species

Assessments should use a framework that identifies all types of threats to biodiversity, not only the threat posed by climate change. The magnitude of climate change as a threat to biodiversity is generally unknown. It may accentuate the other direct threats listed above, especially habitat loss and the threat from invasive species. In its Climate Change and Development Strategy, USAID considers climate change to be a "threat multiplier" (USAID, 2012a, p. 4).

To support the ***role of biodiversity in societal adaptation to climate change***, what is needed is a holistic framework that focuses on the benefits of biodiversity to human societies and the vulnerability of those benefits to climate change, and that identifies options for maintaining the resilience of SESs through ***ecosystem-based approaches to societal adaptation to climate change***. These topics are discussed in Section 4.

1.3 USAID CONTEXT

USAID, as a bilateral development agency and not a conservation organization, would be expected to emphasize the human and social development aspects of climate change adaptation. However, USAID's thinking and guidance about the importance of biodiversity conservation to sustainable development has evolved in the past two decades, and now the Agency states that "Biodiversity is the very foundation for all the Earth's essential goods and services. The air we breathe, water we drink, and the food we eat all depend on the Earth's rich biodiversity" (USAID, 2013a). In other words, biodiversity is the foundation for development.

USAID's policies and guidance generally describe both climate change adaptation and biodiversity conservation as cross-cutting, cross-sectoral issues and needs. USAID's ***Climate Change and Development Strategy***, for example, states that "Consideration of climate change… across a wide range of development sectors is essential to the success of USAID's mission" (USAID, 2012a). In ***Adapting to Climate Variability and Change: A Guidance Manual for Development Planning*** (USAID, 2007), climate change vulnerabilities and options are described for all development sectors, including democracy and governance, health, agriculture, natural resources management, coastal zone management, economic growth and trade, energy, water, humanitarian assistance, and conflict. Similarly, for biodiversity USAID's ***Biodiversity Conservation: A Guide for USAID Staff and Partners*** states that "One of USAID's strengths in biodiversity conservation is its insistence that biodiversity conservation be integrated with development activities and goals," and that "We have… expanded the vision of biodiversity conservation cross-sectorally by actively linking with other sectors to … take advantage of cross-sectoral synergies…" (USAID, 2005a). The Biodiversity Guide discusses cross-sectoral linkages with agriculture, biotechnology, conflict, enterprise development, climate change, humanitarian assistance, health and population, extractive industries, urban issues, and water resources.

We found, however, that in practice these issues seem sometimes to be viewed by some people in USAID as "sectors" for programming. The Agency has separate funding streams for biodiversity, climate change adaptation, and climate change mitigation. In the case of biodiversity conservation this funding is even called a "biodiversity earmark" (USAID, 2013b). Each of these themes has its own top-level standard indicators for performance monitoring and evaluation, just as do other USAID development sectors (U .S. Department of State, 2011). This fact presents a challenge for the Agency in implementing its stated view of the role of biodiversity as the foundation for sustainable development, and of climate change adaptation and biodiversity conservation as cross-sectoral issues.

These two contrasting views within USAID are relevant to this study, because ***climate change adaptation for biodiversity conservation*** falls mainly within the sectoral view of biodiversity conservation and climate change adaptation. From this viewpoint, biodiversity conservation –

like agriculture, health, economic growth, water resources, or humanitarian assistance – is treated as one of many "sectors" in need of strategies for adapting to climate change. On the other hand, in ***biodiversity conservation for societal adaptation*** to climate change, both biodiversity conservation and climate change adaptation are seen as cross-cutting means to sustainable development. From this viewpoint, they need to work together cross-sectorally toward sustainable development through ecosystem-based approaches to adaptation, and through building resilience in social-ecological systems.

1.4 COMPARING ASSESSMENT METHODOLOGIES

We compared 15 of the most current and extensive climate change assessment methodologies, frameworks, or guidelines from a representative range of governmental and nongovernmental organizations on some key dimensions related to the integration of climate change adaptation and biodiversity conservation (see Annex D). We analyzed whether they discuss:

- Social systems, ecosystems, or both;
- Strategies for: 1) adaptation for conservation, 2) conservation for adaptation, and 3) "do no harm" to conservation from adaptation measures;
- Ecosystem-based adaptation opportunities (or ecosystem services); and
- The concept of ecological and/or social resilience.

From this comparative analysis we conclude that:

1. Only some assessment methodologies, frameworks, and guidelines – six of the 15 we reviewed – are integrated from the viewpoint of climate change adaptation and biodiversity conservation. Some deal with social systems only (5/15), while others deal with ecological systems only (4/15). This seems to indicate that the need for integrating biodiversity conservation and climate change adaptation has not become a completely "mainstream" concept.

2. There are several good examples of conceptual frameworks for integrating climate change adaptation and biodiversity conservation that:

- encompass both social and ecological systems,
- treat both adaptation for conservation and conservation for adaptation,
- explicitly address ecosystem-based approaches to adaptation, including conserving ecosystem services, and
- apply the concept of resilience to both social and ecological systems.

These frameworks can serve as models for further development and testing of an integrated approach (CBD, 2009a; TNC, 2010; WRI, 2011).

3. Integrated methodologies often place strong emphasis on the ecosystem services created by biodiversity and on the need maintain those for societal adaptation to climate change through ecosystem-based approaches to adaptation (e.g., CBD, 2009a; IUCN, 2009, 2010; TNC, 2009, 2010).

4. Many, but not all, conservation organizations deal only with climate change and ecological systems (e.g., National Wildlife Federation, 2011; WCS, 2012; WWF, 2003). Some, but not all, development-oriented organizations or agencies deal only with climate change and social systems (e.g., CARE, 2009; IISD, 2009; UNDP, 2010; USAID, 2007).

5. Assessments that deal with social systems only do not address either the need for adaptation for biodiversity conservation or biodiversity conservation for societal adaptation.

6. Use of the concept of "resilience" is widespread, but only some (4/15) of the frameworks we reviewed use the term to refer to both social and ecological dimensions of social-ecological systems (SESs). In many it is used with reference to social systems only (7/15), or ecological systems only (3/15).

The implications of these findings, and the recommendations that flow from them, are discussed in the Conclusions and Recommendations section of this report.

2.0 PREDICTING CLIMATE CHANGE

Predicting climate change is the first step in either adapting biodiversity conservation strategies to climate change, or developing strategies for ecosystem-based approaches to societal adaptation to climate change. Climate change has not been historically uniform, and has varied spatially; therefore, before vulnerability can be assessed, assessment teams must determine what changes in climate are most likely within their focal region. This section therefore provides a review of sources of climate data, historical climate trend analysis and climate projections, and discusses model reliability and limitations

2.1 CLIMATE DATA

Weather station data provide a record of climate variables over time. Although many modern weather stations collect data automatically, the vast majority of the information used in statistical summaries of climate and in climate models has been collected by tens of thousands of people manually recording data onto paper for well over a century. International organizations such as the International Maritime Organization, World Meteorological Organization, and the Global Climate Observing System encourage collection and facilitate sharing of meteorological observations; they also invest in digitizing, error checking, and adjusting the data to account for known problems and biases. During the past 20 years, major improvements in the global weather station data available for analysis have been made. Some of these improvements come from establishing new weather stations, but a large amount of information has also come from digitizing paper records and collating historical data from stations from all over the world. Many of the gaps in geographic coverage have been filled; the quantity of data through time has increased; and the archiving, digitizing, and sharing of climate data is ongoing. In Africa, meterological information is not being widely shared, mainly because many African countries do not make their meteorological data publically available and because of the high costs of acquiring and sharing it (Voice of America, 2011).

Because weather stations are generally widely scattered, determining the climate at a specific site usually requires spatial interpolation using records from stations located closest to the site. Many climate variables are available now in interpolated, continuous, spatial formats (e.g., a grid map); but the reliability of interpolated layers varies regionally and it is important to investigate the distribution of the underlying weather station data for a region in order to understand how reliable an interpolated model may be. Weather stations are relatively sparsely distributed in many developing countries, particularly over the interiors of South America and Africa; and this deficiency of data results in reduced quality of interpolated climate information in these regions.

2.2 TREND ANALYSIS AND CLIMATE MODELS

The Berkeley Earth Surface Temperature Study (BEST) is a simple trend analysis and does not depend on the complex mechanistic global climate models, which have been criticized as having hidden assumptions and adjustable parameters by climate change skeptics. BEST has created a merged data set combining 1.6 billion temperature reports from 16 data archives, representing over 36,000 unique weather stations, to produce a global data set approximately five times larger than had previously been analyzed. In 2012 BEST released analysis of land-surface temperature records for the last 250 years, reaching back about 100 years beyond previous studies (BEST, 2012). The BEST analysis shows that the Earth's average land surface temperature has risen by 1.5 °C over the past 250 years, since 1753. The BEST website contains a tool for looking up historical temperature changes by location (e.g. country or city), which provides easy-to-interpret graphs and data tables.

The simplest predictions of future climate change simply project future climate change based on historical rates of change, such as those produced by BEST, and do not consider any mechanisms underlying the prediction. These can serve as baselines for simple, site-specific vulnerability and adaptation assessments, because the historical trends and projections can be clearly communicated to communities and stakeholders. Such projections of historical trends are relatively immune to criticism by climate skeptics, but are limited by their simplicity and the fact that they do not consider how the range of different potential rates of greenhouse gas emissions would affect climate over time. Major changes of state of the climate system – major "regime shifts" – that might occur because of climate thresholds, "tipping points," and unknown emergent properties of the system cannot be predicted from simple extrapolation of trends.

Climate models are used to produce spatial interpolations of the current climate, as well as to predict future climates. They depend on statistically determined relationships between the large number of variables that influence Earth's climate system. General Circulation Models (GCMs) simulate as much as possible about the climate system, such as interactions between the gases in the atmosphere and incoming and outgoing radiation (i.e., the "greenhouse effect"), the way the atmosphere circulates, cloud formation and precipitation, interactions between the atmosphere and the oceans, and land cover change (e.g., snow and ice cover, vegetation change). GCMs try to model how all these different components of the climate system interact, and how the feedback processes between them work. The complexity and predictive accuracy of these models has improved markedly since the beginning of the Intergovernmental Panel on Climate Change (IPCC) in 1988. Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) are the most complex models currently in use. These combine two general circulation models; one for the atmosphere, and one for the oceans. Having established statistical relationships between model components based on historical data, these models can then make predictions by varying the key components such as the atmospheric concentration of CO_2 and other greenhouse gases.

GCM models require extremely large and fast computers, so a number of specialist climate modelling centers have emerged such as the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, the Hadley Centre in the United Kingdom, and the National Center for Atmospheric Research (NCAR) in the United States. These centers produce models of future climate change for a range of different greenhouse gas emissions scenarios, which also involves the separate modeling issue of predicting future rates of emissions of greenhouse gases and their levels in the atmosphere. Greenhouse gas emissions depend in part on human economic activities, so predicting their future levels is the realm of socio-economic modelers. The IPCC has developed sets of socioeconomic assumptions, relating to demographic, social, economic, technological, and environmental factors. Each of these factors are incorporated within feasible future "narratives", or story lines, to produce sets of potential future global greenhouse gas emissions scenarios. The IPCC tracks the trajectory of real emissions through time, comparing them against their models, and regularly revises the socioeconomic assumptions upon which their global greenhouse gas emissions scenarios are based (IPCC, 2007).

Most climate change modeling centers provide their own climate model download options, presenting historical, current, and future climate variables from one or more modeling methods for a range of emissions scenarios, such as those produced by the IPCC.

Worldclim (www.worldclim.org) is a very useful resource, providing a range of downloads options (ASCII grids, ESRI grids), for different climate models (currently 23 models), and IPCC greenhouse gas emissions scenarios (currently five scenarios), for a range of different grid sizes (30 seconds to 30 minutes) at decadal intervals into the future (up to 2080).

2.3 CLIMATE PROJECTIONS

The IPCC (2007) defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer." This definition neatly identifies the two major areas for focus in climate change impact assessment and adaptation planning: changes in average conditions, and changes in the variability around the average.

The IPCC Fourth Assessment Report (2007) provides considerable detail on expected climate changes. Global warming has not been, and is not likely to be in future, either steady or the same in different seasons or locations. Although mean global temperature is projected to continue increasing, there is considerable variation in regional projections. The tropics are projected to experience relatively little warming compared to the high latitudes, with the greatest warming predicted to occur in polar regions. In a future warmer climate, the current generation of models predict that precipitation will generally increase in the areas of regional tropical precipitation maxima (such as the monsoon regimes) and over the tropical Pacific in particular, with general decreases in the subtropics. In terms of climate variability, climate models predict that high-latitude regions will experience the greatest average annual temperature increases, and that the associated variations around the mean will be the largest variations globally. For this reason the high latitudes are often regarded as more vulnerable to climate change than tropical regions. However, the absolute range between climatic extremes is not necessarily the best predictor of impact, and the relative change in variation of temperature and precipitation distributions is likely to be a better indicator. As tropical regions have historically experienced very little daily or seasonal climatic variation they may be highly affected by small increases in such variation. High latitudes have historically experienced relatively greater daily and seasonal variation in climate, meaning that the increase in the variation predicted for the future is a relatively small change.

With regard to tropical regions, the IPCC (2007) states that:

- Cold days, cold nights, and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent.

- Long-term trends from 1900 to 2005 have been observed in precipitation over many large regions. Significantly increased precipitation has been observed in eastern parts of South America, and northern and central Asia. Drying has been observed in the Sahel, southern Africa, and parts of southern Asia. Precipitation is highly variable spatially and temporally, and data are limited in some regions. Long-term trends have not been observed for the other large tropical regions assessed.
- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Increased drying linked with higher temperatures and decreased precipitation has contributed to changes in drought.
- The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour.
- Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. There is no clear trend in the annual numbers of tropical cyclones.

2.4 CLIMATE MODEL RELIABILITY AND LIMITATIONS

Since 1988 increasing numbers of climate modeling groups have produced GCMs, and comparisons to assess the variation across a range of GCMs are frequently made in order to gauge agreement between them all. Within any single GCM a significant source of variation in future climate change predictions lies in the variability of outputs from separate runs of the GCM, known as "realizations." Analysis of variation in realizations has become possible only since the IPCC Fourth Assessment Report (IPCC, 2007) and a convincing case for using "ensembles" consisting of at least fourteen realizations has been made (Pierce, et al. 2009). The use of an ensemble climate model, a single model incorporating multiple realizations for a range of GCMs, can greatly simplify vulnerability and adaptation assessments, because it avoids the need to run multiple assessments using a range of different GCMs.

Two main methods (dynamic and statistical) are used to downscale the course grain/large spatial scale outputs of GCMs to finer grain/smaller spatial scale regional climate models (RCMs). Downscaling incorporates fine-scale topographic and habitat heterogeneity and the effects of local weather patterns. Downscaling produces better results for some climate variables than others, and for some regions more than others. RCM temperature variables are generally regarded as more locally accurate than precipitation variables. This is because local and regional precipitation patterns depend on topography interacting with atmospheric circulation patterns such as *El Niño*, the North Atlantic Oscillation. It is difficult to accurately incorporate these circulation patterns into the downscaling methods, and it is also expected that these circulation patterns are likely to undergo rather unpredictable changes as a result of global climate change.

3.0 ADAPTATION FOR CONSERVATION

Adjusting or adapting biodiversity conservation strategies and activities to take into account the fact that Earth's climate is changing could be called "adaptation for conservation" or "climate-sensitive conservation." The development of adaptation strategies for biodiversity conservation starts with an assessment of the effects of predicted climate changes on species and ecosystems – essentially a vulnerability assessment for biodiversity. Options for adjusting conservation strategies and actions to address these vulnerabilities can then be identified. We found many examples of conceptual frameworks designed to carry out these two steps (FAO, 2012; National Wildlife Federation, 2011; WCS, 2012; WWF, 2003). The following section presents a summary of the main issues related to assessment and programming for adaptation for conservation.

3.1 PREDICTING THE EFFECTS OF CLIMATE CHANGE ON BIODIVERSITY

The modern concept of biological diversity, or "biodiversity" for short, encompasses the variety and variability of life at three levels of organization: ecosystems, species, and genes. As discussed in Section 1.2, climate change is only one of five main categories of direct, biophysical threats to biodiversity. It is a threat of unknown magnitude, and it is likely to accentuate other kinds of threats, especially the conversion of natural ecosystems to agriculture and other uses, which is currently the main threat to biodiversity worldwide.

In the previous section we summarized observed trends in climate change and discussed climate models and projections. Predicting the effect of climate change on biodiversity from climate projections involves layering ecological models on climate models, greatly compounding the errors and uncertainties of the predictions for biodiversity.

Effects on Ecosystems

Climate change is predicted to have several different kinds of effects on ecosystems (Bellard et al., 2012; CBD, 2009b), including changes in their:

- distribution,
- composition,
- structure,
- dynamics and successional processes, and
- ecological processes and functions.

One of the most certain predictions is that the ranges of some species will expand into new regions under future climate conditions, and in many cases those species will compete with established species and thereby affect the composition, structure, and functioning of ecosystems (CBD, 2009b). Research suggests that ecosystems "…will see dramatic reorganizations in coming decades owing to shifting invasive potential by nonnative species" (Peterson, et al., 2008) associated with climate change.

Research is beginning to show that climate change can affect pests, pathogens, and parasites, directly affecting some species and indirectly affecting ecosystems (Ayres and Lombardero, 2000; Sturrock, et al., 2011). Some insects such as mountain pine beetle appear already to be responding to climate warming, creating historically unprecedented levels of forest death in western North America, for example (Mitton and Ferrenberg, 2012). Forest pathogens and diseases such as Sudden Oak Death and White Pine Blister Rust are expected to shift in distribution and expand in range in response to climate change (Kliejunas, 2011). Forest management options that can help forests adapt to climate change include applied research, monitoring, risk assessment and forecasting, planning, and new policies (Sturrock, et al., 2011).

Climate change is predicted to affect the frequency of fire in ecosystems because of its effects on temperature and precipitation. In one study, fire potential as measured by a commonly-used drought index that combines temperature and precipitation was projected to the end of this century using GCMs; and future wildfire potential showed significant increases in the model in the United States, South America, central Asia, southern Europe, southern Africa, and Australia (Liu et al., 2010).

Both climate change and biodiversity loss have the potential to cause major "regime shifts," or changes in state, of social and ecological systems. Ecologists and other systems-oriented scientists would generally agree that it is not possible to predict those regime shifts through even the most extensive modeling, because models are based on only a few known parameters of the systems, and because the complexity of the systems and their emergent properties make them impossible to fully model.

Effects on Species

Many authors over the last decade have discussed the observed and the potential effects of climate change on species (Bellard et al., 2012; CBD, 2009b). The main effects are predicted to be:

- changes in distribution or range, including latitudinal shifts, altitudinal shifts, and range contractions or expansions; and
- changes in population dynamics, due to a range of direct climate-related factors such as increases in temperature, precipitation, extreme events, and fires; or indirect factors such as increased competition from native species; or the spread of invasive species, pests, or pathogens; or loss of pollinators.

The adaptive responses of species to climate change can involve migration to suitable habitats, developmental responses, and genetic evolution (Noss, 2001). Movements and range shifts, including changes in latitudinal and altitudinal range limits, are the most common response observed so far (Chen et al., 2011; Davis, 2001; Franco et al., 2006; Hickling et al., 2006; Knight et al., 2007; Parmesan et al., 1999; Raxworthy, et al., 2008; Wilson et al., 2005; 2007). The ranges of many species have already shifted toward higher latitudes, and many have shifted to higher altitudes, as predicted under a warming global climate. Species inhabiting cold extremes such as the tops of mountain ranges, the highest latitudes, or the coldest seas, are the most likely candidates for climate-driven extinction, as they have very limited options to move to find more suitable climates. Opposite responses have also been noted (Lenoir et al., 2010; Thomas, et al., 2006) although less frequently. Both range reductions and range expansions have been observed, the latter observation calling attention to the fact that some species are likely to benefit from climate change.

It is commonly reasoned that warm adapted tropical species are less threatened than high latitude species, as they should be able to move their ranges polewards to track their favored climate. However, many tropical species are already living in the Earth's warmest zones and close to their maximum thermal tolerances, making them highly vulnerable to slight increases in temperature. Warm water coral species are commonly regarded to be highly threatened for this reason. Indeed the last thirty years of climate warming, particularly the increased frequency and intensity of cyclical warming events, has caused extensive bleaching and damage to some coral reefs. While community level predictions are relatively easy to make (i.e., the more extreme the warming event the more damage is likely to occur to coral reefs), due to limited data on species individual tolerances and to complex and unpredictable interactions between species, it remains difficult to predict exactly which individual species are the most vulnerable.

For corals, for example, an example from Mozambique is instructive. Because of the large latitudinal range of its coastline, and range of water temperatures found there Mozambique's reefs have a rich diversity of corals, with an estimated 300 species of hard corals and more than 50 species of soft corals. Fringing reefs are generally dominated by hard corals, while rocky reefs are colonized mainly by soft corals. Each species is likely to have its own unique – and currently unstudied – tolerance to temperature and other biophysical factors (USAID–Mozambique, 2012). It is impossible to predict with certainty exactly which species may tolerate further warming of these warmest zones, and how communities may adapt and re-assemble in such regions.

The influence of climate change on the timing of many natural events, which biologists broadly refer to as "phenology," have been documented for many species. In plants, changes in the timing of emergence, leafing out, flowering, fruiting, and leaf loss, have all been documented. Hundreds of papers have been published in the last five years documenting phenological changes for plants and animals (Cleland et al., 2007; Parmesan and Yohe, 2003, Parmesan, 2006). These phenological changes have the potential to affect species' populations directly or indirectly (CBD, 2009b, p. 26), affecting important ecological characteristics such as food webs, ecological functioning, and potentially ecosystem services.

In addition to the direct effects of climate change, its indirect effects – and often its synergistic effects in combination with other threats – are likely to threaten some species:

- the sea level rise that climate change will cause is a significant threat to coastal and littoral biodiversity;
- ocean acidification is a threat to some marine organisms;
- changes in fire regimes area likely to threaten some species, especially forest species; and
- changes in the distributions of pests and pathogens are predicted, potentially threatening some species.

In a review of species-specific threats and the range of possible responses the IPCC 2007 Fourth Assessment Report stated that "up to 30 percent of higher plant and animal species would be at high risk of extinction with a warming of 'only' 1.5-2.5°C over present temperatures. Many species have suffered population declines that have been attributed to the effects of climate change, acting through a range of mechanisms. However, other species have increased in both abundance and breadth of distribution" (CBD, 2009b, p. 24). One of the major challenges in determining threat is that the spectrum of other anthropogenic threats (e.g., overharvesting, pollution, habitat degradation and fragmentation, etc.) are likely to act in unpredictable synergies with climate change. Foden et al, (2008) provide an expert assessment of the threat of climate change to all known species of corals, birds and amphibians. They find that 68-83 percent of species which are currently classified as threatened to varying degrees will be further threatened by climate change, and 28-72 percent of species which are currently not classified as threatened are likely to become threatened due to climate change. This large degree of uncertainty on severity of impacts of climate change on presently non-threatened species demonstrates the current challenge of planning for climate change through biodiversity programming.

To predict how species will respond to climate change, scientists often use rainfall and temperature data in mathematical models known as Species Distribution Models (SDMs) to predict species distributions and potential range shifts. These models are also often called Environmental Niche Models, or Climate Envelope Models. They essentially model a species "comfort zone" under current and future climates. Zimmerman et al. (2009) demonstrate that "measures of climate extremes are important for understanding the climatic limits of tree species and assessing species niche characteristics" and recommend that "inclusion of climate variability likely will improve models of species range limits under future conditions, where changes in mean climate and increased variability are expected."

Although they can provide useful general indications of future responses to climate change, there are a number of cautions that accompany the use of SDMs. They are often developed based on the assumption that the current distribution of a species reflects its full "comfort zone," whereas in most cases species distributions have also been limited by other factors. Many rare and endangered species have only been located in a few places and therefore their modeled distribution is based on only a few locations/data points. Few SDMs consider species inter-dependencies (e.g. pollination, seed dispersal) or inter-actions (e.g. competition or predation). Further drawbacks of SDMs are that they do not take into account the likelihood that a species is able to reach and colonize the potentially suitable area, or the need for habitat changes to precede species dispersal. Dispersal and migration rates are widely regarded as the most significant uncertainties in using SDMs to predict climate change threats to particular species. SDM tools have evolved and improved greatly in their ease of use, but a large quantity of accurate distribution records are necessary and technical expertise is required to use them to support biodiversity or forestry program planning. Some regional biodiversity data services provide SDMs for some species, for current and future climate scenarios. If relevant models can be sourced from such services this can save programs substantial amounts of time and effort. While SDM's are generally useful to raise awareness of potential impacts of climate change on species distributions, and do point to some general trends (i.e. polewards and altitudinal range movements) a great deal of specialist knowledge is required to determine how well a SDM is likely to perform in predicting the distribution of an individual species under future climate conditions. Lack of precision at the local scale and the general lack of relationship to the ecological processes that drive species interactions on the ground are major limitations for active planning at the species level for climate change.

Because the responses of individual species to climate change are difficult to predict, another way to assess the general vulnerability of species in a given ecosystem is to assume that the larger the potential change in climate in a given place, the greater the vulnerability of species found there. Williams, et al. (2007) and Beaumont, et al. (2011) modeled global climate change using the IPCC 2007 scenarios, and produced maps showing where the greatest overall changes in climate are likely to occur. The results of these climate change assessments can then be overlain with maps of ecosystems, protected areas, species distributions, or species richness to predict which of these are most likely to be affected by climate change, and where. A recent assessment of the potential impacts of climate change on biodiversity in Central America, Mexico, and the Dominican Republic is an example of the application of this kind of modeling (CATHALAC, 2008).

Effects on Genetic Diversity within Species

Genetic diversity within populations of a species allows the species to adapt through evolution to changing biophysical conditions. Climate change is predicted to affect genetic diversity and the evolutionary processes that maintain it. Genetic diversity is important commonly regarded as an important factor in determining the resilience of species to climate change and to other threats as well (Botkin et al., 2007). For example, experimental work has shown that eelgrass communities are much more resilient to increased temperature when they include high genetic diversity (Ehlers et al*.,* 2008). In the eelgrass example, "genetic diversity within a single species is crucially important for continued ecosystem function" (CBD, 2009b, p. 28).

The range-shifts of species in response to climate change that were discussed above can also affect genetic diversity within the species. Genetic diversity within populations reflects their evolutionary adaptation to local environments, and populations at the extremes of a species range are often genetically different than those in the center. Conserving populations throughout the species range will maximize genetic adaptability to a changing environment (EPA, 1999; Hampe and Petit, 2005; Noss, 2001).

Studies of population-genetic patterns attributed to climate changes of the past indicate that the ranges of many species contracted to "refugia" – pockets of suitable climate – during past ice ages or warm periods, depending on the species, and so the populations and genotypes currently remaining in those areas may often be especially ancient and diverse. Several studies have proposed that past climate refugia should be conservation targets. However, the conditions during most recent climate fluctuations, including past ice ages were the reverse (generally colder and drier) of those that are projected for the future (generally hotter and wetter), so it is not clear how "pre-adapted" populations from these regions will be to future climate change.

Overall, the most effective strategy for preserving genetic diversity within species is likely to include conserving populations of each species over as large a part of their range as possible, maximizing the size of populations and habitat patch sizes as much as possible, and maintaining dispersal corridors to allow movement (of either plants or animals) that will reduce inbreeding and loss of genetic diversity.

Agro-biodiversity

Agro-biodiversity can be defined as the diversity of cultivated and livestock species and their genetically distinct varieties, as well as wild and semi-domesticated food and medicinal plants. Traditional farming and grazing systems have evolved over centuries to meet the challenges and uncertainties associated with climate, soil resources, animal and plant pests and diseases, and other sources of environmental variability. Traditional farming systems often include more species, and greater structural and temporal complexity than "modern" farming systems, which allows them to more fully exploit water, sunlight, and nutrients while minimizing inputs of labor, fertilizer, and water. In Kenya, numerous studies have shown that farmers who maintain agro-biodiversity by growing a diversity of traditional crops and varieties, and using indigenous fruit trees, have higher food security than farmers who do not (USAID-Kenya, 2011). Tanzania has a number of well-studied traditional agricultural systems that represent existing strategies for resilience to past climate variability, and which are likely to be adaptive and resilient across a range of future climate changes. Agricultural development programs can help communities to maintain climate resilience through support for conserving the agro-biodiversity of traditional crops and the genetic diversity of traditional plant and animal varieties (USAID-Tanzania, 2012).

Effects on Ecological Processes

The species in an ecosystem interact with each other and the physical environment, creating ecological processes, or functions, such as:

- the capture and chemical storage of solar energy by plants in the process of photosynthesis;
- flows of energy through complex pathways in food webs, from primary producers, to herbivores, carnivores, and decomposers; and
- cycles of materials, called nutrient, or "biogeochemical" cycles, through food webs and back to the physical environment (e.g., water cycle, carbon cycle, nitrogen cycle).

Climate change could alter or disrupt any of these ecological processes, from which humans derive ecosystem products and services. For example, forest ecosystems provide hydrological ecosystem services – predictable flows of clean water. A global assessment of recent tree mortality attributed to drought and heat stress suggests that at least some of the world's forest ecosystems are already responding to climate change in ways that threaten the ecosystem services they provide, such as hydrological services (Allen et al., 2010).

Pollination is a critical ecosystem service that makes a significant contribution to human agriculture, and "recent evidence suggests that mismatches in phenological responses to climate change between plants and pollinators may significantly affect their interactions" (Bertin, 2008). Models suggest that climate change effects on flowering will reduce the food available to up to half of all species of pollinators, threatening this ecosystem service (CBD, 2009b, p. 29). A recent analysis of pollinator activity patterns demonstrates how native bees could buffer the negative impact of climate warming on honey bee pollination (Rader, et al., 2013), providing an important example of how biodiversity can provide resilience against environmental change.

3.2 IDENTIFYING OPTIONS FOR ADAPTING BIODIVERSITY CONSERVATION TO CLIMATE CHANGE

As we noted in Section 1.4, many assessment frameworks focusing on threats to biodiversity from climate change have been developed by conservation organizations and agencies in the last decade. USAID's framework for the tropical forests and biodiversity analyses mandated by Sections 118 and 119 of the Foreign Assistance Act treats climate change as one of the five main direct threats to biodiversity (USAID, 2005b). There is a large body of recent literature that discusses how to assess the vulnerability of biodiversity to climate change and incorporate those considerations into conservation planning (Spittlehouse and Steward, 2003; Millar et al., 2007; Guariguata, et al., 2008; Heller and Zavaleta, 2009; National Wildlife Federation, 2011; Cross et al., 2012).

The article "Beyond Kyoto: Forest Management in a Time of Rapid Climate Change" (Noss, 2001) provided one of the first comprehensive checklists of actions needed for maintaining forest biodiversity and ecosystem services in the face of climate change, and proposed that to conserve biodiversity we need to:

- represent forest types across environmental gradients in reserves;
- protect climatic refugia at multiple scales;
- protect primary [late-successional/old-growth] forests;
- avoid fragmentation and provide connectivity, especially parallel to climatic gradients;
- provide buffer zones for adjustment of reserve boundaries;
- practice low-intensity forestry and prevent conversion of natural forests to plantations;
- maintain natural fire regimes;
- maintain diverse gene pools; and
- identify and protect functional groups and keystone species.

However, Noss concluded that: "Good forest management in a time of rapidly changing climate differs little from good forest management under more static conditions…"

Another early comprehensive treatment of this topic is found in "Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems" (WWF, 2003).

The actions needed that are proposed there are consistent with the CBD review of climate and biodiversity linkages (CBD, 2009b), which promotes the following goals:

- maintaining viable populations of species and sufficiently large areas of ecosystems to ensure their resilience and ability to provide ecosystem services;
- ensuring connectivity between populations and habitats so species can shift their distributions in response to climate change; and
- reducing other threats to ecosystems and species.

The CBD suggests that these goals can be met through changes in the extent and design of protected area systems, changes in protected area management, and management of the wider landscape to ensure ecological connectivity (CBD, 2009b, p. 68). These are social challenges, primarily, calling attention to the need for fully embedding social considerations into conservation and taking a social-ecological approach to conservation planning (Ban, et al., 2013; Ostrom, 2009).

In many cases biodiversity vulnerabilities can be identified and adaptation measures devised, at least in the short-term, without extensive modeling of climate change effects. Understanding the spatial and temporal distribution of climate change at the landscape scale is more important than trying to understand changes at the level of individual species. An expert group of conservation biologists (Cross, et al., 2012, p. 1) says that "Our framework… is based on the premise that effective adaptation of management to climate change can rely on local knowledge of an ecosystem and does not necessarily require detailed projections of climate change or its effects." None of these statements argue against some modeling and attempts to predict future climate. Rather, they seem to show general agreement that there are many adaptation activities that can be started without extensive modeling, and modeling usually does not change the core elements of the plan anyway.

If species-response or ecological models are available, their use can provide information for more sophisticated project or program design. While they are widely agreed to be useful, projections from models always have a level of uncertainty. Although species-response and ecological models have improved greatly over the last decade, it is often difficult for conservation practitioners to understand and integrate model uncertainty into decision making processes. Comparing the predictions of such models with the actual responses of species and ecosystems for a few years into the future will enable an assessment of their reliability and facilitate their improvement. Some general principles regarding uncertainty in species and ecological models include:

- the greater the climate change the less reliable are the predicted biological responses;
- although models are often reliable in predicting the general direction of a biological response, the rates of response (e.g., range shifts) are likely to lag behind the rates predicted by the models to a largely unpredictable degree;
- unpredictable interactions between species are likely to affect the reliability of many models; and
- it is impossible to include all potentially influential environmental variables, and variables that are omitted from models may be more important in the future than we realize now.

4.0 CONSERVATION FOR ADAPTATION

Developing climate change adaptation strategies and activities to take into account the important role of biodiversity in societal adaptation to climate changes could be called "conservation for adaptation." Conserving biodiversity as an approach to climate change adaptation first requires an assessment of how the benefits that biodiversity provides to human societies may be affected by predicted climate changes; and, second, the identification of options for maintaining those benefits as a significant component of climate change adaptation strategies. We found several examples of conceptual frameworks that take this approach in our review of the literature (CBD, 2009a; TNC, 2010; WRI, 2011). Two concepts that are gaining attention – ***ecosystem-based approaches to adaptation*** and ***resilience*** – are especially relevant to conservation for adaptation. The following section presents a summary of the main issues for assessment and programming for conservation for adaptation.

4.1 SOCIETAL BENEFITS FROM BIODIVERSITY

Biological diversity provides social and economic benefits of three distinct kinds: ecosystem products, ecosystem services, and non-material benefits (USAID, 2005a). Ecosystem products are the direct material benefits that people get from wild species, such as for food, building materials, medicines, and fuel. Ecosystem services are best defined as the benefits to humans that result from ecosystem functions and processes (Ecological Society of America, 2012), such as:

- major biogeochemical and nutrient cycles (e.g., of water, carbon, nitrogen, phosphorus);
- natural pest control by predators in food webs;
- pollination by insects, bats, and birds;
- decomposition of biomass, wastes, and pollution;
- soil formation, retention, erosion prevention, and maintenance of soil fertility; and
- climate regulation.

The diverse species in a given environment interact with each other and the physical environment to create the ecosystem functions and processes listed above. Biodiverse ecosystems are the source of ecosystem services (Byers, 2012), so biodiversity conservation is therefore a fundamental requirement for conserving ecosystem services (Cardinale, et al., 2012).

The role of species diversity in maintaining ecological processes and functions is not completely understood scientifically, and is an active topic of scientific research. However, "there is now unequivocal evidence that biodiversity loss reduces the efficiency by which ecological communities capture biologically essential resources, produce biomass, decompose and recycle biologically essential nutrients" (Cardinale, et al., 2012).

USAID's recognition of the fact that the ecosystem products and services provided by biodiversity are fundamental to sustainable human development is not new (USAID, 2005a; 2012b), and ecosystem-based approaches to adaptation simply extend this recognition to the arena of development in an era of changing climate. The view that there is a two-way relationship between biodiversity conservation and climate change adaptation is recognized by USAID in a Biodiversity and Climate Change Internal Brief (USAID, 2010), which summarizes conclusions from the scientific sources we have already cited, especially the work of the Convention on Biological Diversity (CBD, 2009a, 2009b), and argues that this science should inform its USAID climate change and development policy. The Internal Brief states that "Intact, well-managed ecosystems—including forests, grasslands, oceans, and wetlands— sustain human life and maintain biodiversity, and also play important roles in capturing and sequestering carbon and stabilizing weather patterns and rainfall. Additionally, healthy, biodiverse ecosystems are more resilient and able to withstand or recover from climate change impacts than are degraded habitats. Intact and diverse ecosystems have an increased chance of withstanding the stress of climate changes and therefore being able to continue to provide the ecosystem goods (such as wood or fish) and services (including water cycling, crop pollination, and soil fertility) on which humans depend, and upon which they may need to rely even more in a climate-stressed future. Healthy ecosystems such as mangroves, upland forests and coral reefs also act as buffers against natural disasters; the buffer effect makes biodiversity conservation increasingly important as climate change leads to more frequent and more severe extreme weather events. Hence, the conservation of biodiversity and functioning ecosystems can decrease human vulnerability to climate change."

USAID's Climate Change and Development (CCD) Strategy 2012-2016 says that "Many years of leadership in biodiversity conservation and natural resources management inform climate sensitive approaches to land use planning and sustainable use of natural resources such as forests and water. Recognizing that this is an emerging field and that adaptation needs will vary considerably with local circumstances, USAID will support…. strengthening of environmental conservation actions that protect natural ecosystems on which human development depends" (USAID, 2012a, pp. 16-17). One of the 10 "guiding principles" listed in the CCD Strategy is to "value ecosystem services." Because biodiversity is the source of ecosystem services (USAID, 2005a; Byers, 2012), this principle provides a strong link between climate change and conservation. The CCD Strategy states that: "Although these [ecosystem] services are critical to development, they are often not valued appropriately in the marketplace. For example, forests offer more than just timber for harvest… [they store] carbon; … reduce erosion, improve the quantity and quality of water" (USAID, 2012a, p. 10).

Ecological Resilience and Societal Adaptation

The concept of ecological resilience – like that of ecosystem services– is key to integrating climate change adaptation and biodiversity conservation. This concept was first introduced by the Canadian ecologist C.S. Holling to describe the persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes (Holling, 1973). Resilience has been defined in ecological literature as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al., 2004). In the four decades that this concept has been investigated by ecologists, a large body of work has developed, much of it confined to the academic literature. This thinking is now being actively adapted for natural resource managers and development practitioners (Walker and Salt, 2006). It emphasizes the need to understand and manage integrated social-ecological systems (SESs). "Resilience should be thought of as a framework for systematically thinking about the dynamics of [social-ecological systems] SESs" (Anderies et al., 2006, p. 21). Resilience is essentially the converse of vulnerability to undesirable regime shifts, and adaptation involves actions that maintain or increase resilience.

Many empirical and theoretical studies show that greater species-level biodiversity makes ecosystems more resilient. Their ecological processes are more stable, they are more resistant to disturbance, recover more quickly following disturbance, and are less likely to experience irreversible changes (Cottingham et al., 2001; Hooper et al., 2000; Naeem et al., 2009; Noon et al., 2012; Peterson, et al, 1998). "There is mounting evidence that biodiversity [i.e., species richness] increases the stability of ecosystem functions through time" (Cardinale et al., 2012). Research in North American grasslands has shown that greater species-level biodiversity provides greater resilience to drought (Tilman and Downing, 1994), thereby enabling the ecosystem services they provide – such as water and soil retention, carbon sequestration, and nutrient cycling – to be maintained. For forest ecosystems, "The available scientific evidence strongly supports the conclusion that the capacity of forests to resist change, or recover following disturbance, is dependent on biodiversity at multiple scales" (CBD, 2009c, p. 7). In fact, maintaining and restoring biodiversity in all types of ecosystems makes them more resilient and able to withstand all types of threats, including climate change, and continue to function to produce ecosystem products, services, and non-material benefits.

Dramatic and sometimes sudden ecological changes, called "regime shifts," can occur if ecosystems lose their resilience. Evidence shows that the likelihood of regime shifts may increase if human activities change basic biophysical or biochemical parameters, such as through climate change. Regime shifts are more likely when humans reduce resilience by removing whole functional groups of species, or entire trophic levels, such as top carnivores (e.g., wolves, sea otters, orcas), or alter the magnitude, frequency, and duration of disturbance regimes (e.g., floods, fires). "The combined and often synergistic effects of those pressures can make ecosystems more vulnerable to changes that previously could be absorbed. As a consequence, ecosystems may suddenly shift from desired to less desired states in their capacity to generate ecosystem services" (Folke, et al., 2004). Climate change is clearly a large, unpredictable factor that has the potential to cause major "regime shifts" in social-ecological systems. Short-term adaptive management and coping strategies do not generally address the risks associated with regime shifts, which are largely unpredictable.

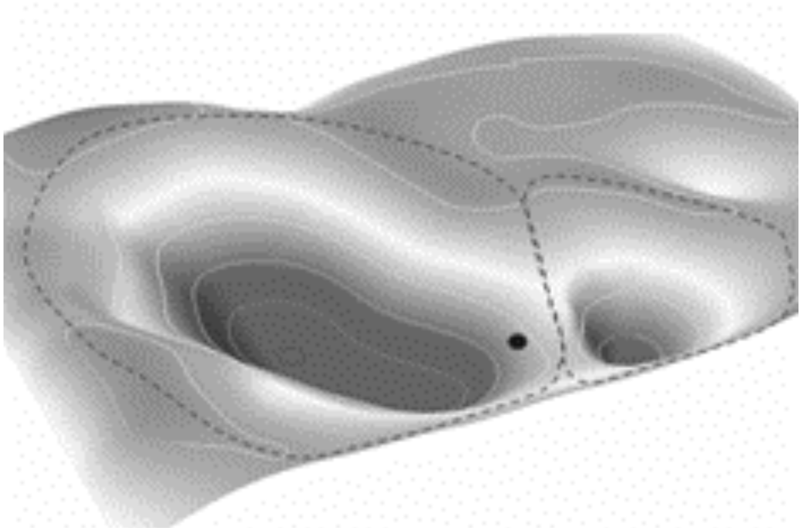


Figure 1. A "stability landscape" used by resilience theorists to describe how a system may have alternative states (represented by the depressions in the surface) between which it can shift in a "regime shift" (Walker, et al., 2004, p. 4). The black dot shows the position of the system on the stability surface now; a small change in variables could move it to the right, in the direction of an alternative "basin" or "regime." If the large basin on the left is "sustainable development," and the small basin on the right is "global collapse," either climate change or biodiversity loss could reduce the height of the "ridge" – represented by the dotted line – between these alternative states. Actions taken for "conservation for adaptation" would seek to increase the height of the ridge, making "global collapse" less likely, and "sustainable development" more likely.

Development organizations and agencies, such as CARE International (CARE, 2009) and USAID (USAID, 2012b) use the term resilience, but in a sense that is limited to social dimensions, rather than to whole social-ecological systems. This use of the term comes from thinking about disaster risk reduction (DRR), which generally has had a relatively short timeframe. Strategic Objective (SO) 2 of USAID's CCD Strategy is to "Increase resilience of people, places, and livelihoods through investments in adaptation," and the term resilience is used many times in the CCD Strategy (USAID, 2012A). In December 2012, USAID released new policy and program guidance for "Building Resilience to Recurrent Crisis" (USAID, 2012b). The need for actions to anticipate climate change risks and prepare for them is now challenging USAID and other organizations to extend the concept of resilience to longer timeframes. In doing so, there would be great benefit in expanding their view from social systems only to the whole social-ecological system, and incorporating ideas from the scientific literature on ecological resilience.

4.2 PREDICTING CLIMATE CHANGE EFFECTS ON ECOSYSTEM BENEFITS

The way in which the interactions between climate change and biodiversity affect the values and benefits derived from nature is of fundamental importance to sustainable development.

Among the benefits that are likely to be most affected by climate change are those from ecosystem products (e.g., fish, forest products) and ecosystem services (e.g., hydrological services, carbon sequestration, nutrient cycling, pest and pathogen control, coastal protection, pollination).

Possible effects on ecosystem products include:

- changes in population dynamics and/or ranges of fish species important to fisheries;
- changes in growth rates and reproductive ecology of valuable timber tree species; and
- changes in availability of economically valuable species dependent on wild pollinators (e.g. durian, Brazil nuts).

Possible effects on ecosystem services include:

- damage to coral reefs and their service of coastal protection from rapid sea-level rise, ocean warming and/or ocean acidification;
- damage to mangroves from sea-level rise and possible hard infrastructure measures taken to prevent it that would prevent landward colonization by mangroves;
- reduction in the hydrological services (water quantity, quality, and flow regimes) provided by forests from increased pest or pathogen outbreaks or wildfires;
- reduced levels of pollination of economically important crops;
- reduced populations of predator species (e.g. bats, birds, predatory wasps), affecting regulation of the pest species they consume; and
- changes in rates of photosynthesis, which is likely to increase at high latitudes but may possibly decrease in the tropics where plants are already operating very close to temperature thresholds above which CO_2 uptake through photosynthesis declines.

Image 2. Bromeliad in the cloud forest ecosystem of La Tigra National Park, Honduras. The leaf and plant architecture of many cloud forest plants, including bromeliads, is an evolutionary adaptation to harvest water from fog and mist. La Tigra National Park occupies the top of the mountains above Tegucigalpa, the capital of Honduras, and is the water source for the city, although at present water users do not pay anything for the conservation of the watersheds that provide their water. Climate change will influence precipitation and evapotranspiration in one way or another -- the climate will either get wetter, or drier. In either case, native biodiversity is expected to provide increased stability and resilience in the ecological processes important in the water cycle. Therefore, conserving native biodiversity, such as that of La Tigra NP, will be beneficial for societal adaptation to climate change. **Photo by B. Byers, 2011**

4.3 IDENTIFYING OPTIONS FOR CONSERVING BIODIVERSITY FOR SOCIETAL ADAPTATION

Biodiversity conservation for societal adaptation to climate change can best be promoted by emphasizing two related concepts, ***ecosystem services*** and ***ecosystem-based approaches to adaptation***. Ecosystem-based adaptation aims to maintain or increase the resilience and reduce the vulnerability of ecosystems, and thereby maintain their provision of goods and services to societies.

Ecosystem-Based Approaches to Adaptation

Until a few years ago, conservation for adaptation had received less attention than adaptation for conservation. Now some organizations are beginning to develop the ecosystem-based adaptation concept (ABCG, 2011; CBD, 2009a; IUCN, 2010; Glick et al., 2011; TNC, 2009; 2010; WRI, 2011). The UNFCCC Nairobi Work Program is involved in providing knowledge and support for ecosystem-based approaches to adaptation (UNFCCC-SBSTA, 2011). The concept of ecosystem-based approaches to adaptation springs from the fact that "Biodiversity…helps people to adapt to climate change through providing the ecosystem services which reduce their vulnerability and enhance their adaptive capacity to change" (IUCN, 2011). The CBD has defined ecosystem-based adaptation as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change" (CBD, 2009a, p. 41). Whereas in adaptation for conservation the actions needed in the face of climate change are taken for the immediate benefit of non-human species, in conservation for adaptation the actions needed in the face of climate change are taken for the benefit of people, through conserving the biodiversity that maintains the life-support systems of the planet.

The USAID Climate Change and Development Strategy calls for an emphasis on ecosystem services (USAID, 2012a, p. 10). Emphasis on these essential and irreplaceable services that result from biodiverse ecosystems provides a rationale for an integrated, landscape-scale approach in the design of projects and programs. USAID's view about the role of biodiversity in development is that it is the foundation upon which all sustainable development rests (USAID, 2005a; 2013a). If that view is accepted, conserving biodiversity is important to all development objectives, and biodiversity conservation becomes – like climate change adaptation – a "cross-cutting" issue, not a development sector or objective in its own right. Taking the view that biodiversity conservation is just another development sector, like health or economic growth, is not compatible with the view that it is the foundation of sustainable development. It is in ecosystem-based approaches to societal adaptation to climate change that adaptation and biodiversity conservation come together to work cross-sectorally toward sustainable development.

Although this is not a new concept, the term "ecosystem-based adaptation" is relatively new; and like many new terms, it is often misunderstood. It is sometimes even confused with adaptation for conservation – helping species and ecosystems to adapt to climate change. An article at WWF's ClimatePrep website warns that ecosystem-based adaptation "means many things to many people," and notes that it has led to mistrust and confusion between conservationists focused on non-human species and those focused on the human benefits of biodiversity to people (Martin, 2011). Some organizations prefer to talk about "integrated approaches" that combine ecological and social dimensions. For example, the Ecosystems and Livelihoods Adaptation Network (ELAN) says that its mission is to promote "…an integrated approach to adaptation, defined as adaptation planning and action that adheres both to human rights-based principles and principles of ecosystem sustainability, recognizing their co-dependent roles in successfully managing climate variability and long-term change" (ELAN, 2013). ELAN started in 2009 as a partnership between IUCN and WWF, with CARE International joining in 2010, and the International Institute of Environment and Development (IIED) in 2011.

Ecosystem-based approaches to adaptation are an important gateway to integrating biodiversity conservation and climate change adaptation, and the term is useful, if used correctly. According to the CBD, "Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies" (CBD, 2009a, p. 41). Because the ecosystem services that result from biodiverse ecosystems are an indispensable part of the life-support systems of the Earth, their conservation and maintenance must be a part of any strategy for sustainable development, including climate change adaptation components of such a strategy. It is not, therefore, a question of choosing between social or technological approaches to adaptation and ecosystem-based approaches to adaptation; ecosystem services ***must*** be conserved in the face of climate change or any social or technological approaches will also fail.

In its extensive review of recent literature on the links between biodiversity and climate change, the CBD notes that "the importance of adopting an integrated approach that incorporates adaptation measures that are based on biodiversity is highlighted throughout the literature" (CBD, 2009b, p. 73).

Ecosystem-based approaches to adaptation include actions to (TNC, 2009, p. 4):

- maintain intact and interconnected natural ecosystems so they can continue to provide ecosystem goods and services to people;
- restore fragmented or degraded ecosystems to increase their resilience and re-establish their ecological functions;
- adaptively manage natural resources to take climate change and its associated ecological effects into account; and
- ensure that any use of renewable natural resources is sustainable under changed climate conditions.

The CDB has identified a number of geographic or sectoral areas for biodiversity to contribute to societal adaptation through ecosystem-based adaptation (CBD, 2009b):

- Coastal adaptation
- Adaptation in the water sector
- Adaptation in agriculture
- Forest adaptation
- Adaptation in the urban environment
- Health.

Ecosystem-based approaches to adaptation can be particularly important to poor people, who are often the most dependent on ecosystem goods and services for their livelihoods and survival (UNFCCC-SBSTA, 2011, p. 4). Although some development planners may wish to use comparative cost information – that is, how much does mangrove conservation cost and how much is its service "worth," compared to a concrete seawall, for example – such cost information does not exist at the present time. Ecosystem services are often not adequately valued by markets (USAID, 2012a), they are often public goods, and are notoriously difficult to value in monatary terms because they are often have no technological substitutes, so it is unlikely that such comparative cost information can be estimated in the future.

UNFCCC National Adaptation Programmes of Action (NAPAs) and emerging promotion of National Adaptation Plans (NAPs) are essentially planning tools for societal adaptation in general (UNFCCC, 2002; 2012b). They do not necessarily incorporate ecosystem-based approaches to adaptation (UNFCCC, 2012a). However, NAPAs and NAPs could provide entry points for the consideration of ecosystem-based adaptation options. In some cases where NAPAs did prioritize ecosystems and biodiversity, those were often treated as a discrete sector in climate adaptation, and not as a cross-cutting issue as we argue here that they should be.

Image 3. Páramo (high-altitude Andean moorland) ecosystem in Los Nevados National Park, Colombia. Páramo is rich in unique species, and critical for maintaining hydrological ecosystem services throughout the northern Andes. The Los Nevados páramo acts as a sponge to store and filter seasonal flows from melting snowpack and glaciers. Climate change will influence precipitation and temperature in one way or another, and in either case páramo is expected to provide increased stability and resilience in the processes important in the water cycle.
Photo by B. Byers, 2009

5.0 AVOIDING THREATS TO BIODIVERSITY FROM ADAPTATION ACTIONS

The need to be aware of potential effects on biodiversity from climate change adaptation measures taken in other sectors (e.g., effects of "hard" infrastructure like seawalls and levies, dams for irrigation and/or flood control, or promotion of irrigated agriculture) has been recognized for at least a decade. WWF's "Buying Time" noted the need for monitoring to assure that climate change adaptation interventions "do no harm" (WWF, 2003). The CBD's 2009 comprehensive review of the literature discusses the impacts of adaptation strategies on biodiversity, and considers the effects on biodiversity of adaptation interventions for coastal defense, water management, agricultural practices, urban environmental adaptation measures, and health. "Climate change impacts can be exacerbated by management practices, such as the development of seawalls, flood management and fire management, that do not consider other sectors such as biodiversity conservation and water resource management; this results in maladaptation in the longer term" (CBD, 2009b, pp. 73-74).

In amendments to Sections 118 and 119 of the U.S. Foreign Assistance Act of 1961, enacted in 1987, Congress imposed mandatory "Country Analysis Requirements" related to the conservation and sustainable use of tropical forests and biological diversity on the U.S. Agency for International Development (USAID, 2005b). A major intent of Congress at the time they enacted these requirements was to avoid harm to biodiversity from USAID-funded development assistance. This was a response to the growing evidence that many donor-funded projects during the previous decade or two, such as the construction of roads and large hydropower projects in the Amazon Basin, had been extremely harmful to biodiversity.

Maladaptive actions are generally based on narrow, sectoral, short-term solutions to problems and challenges, without taking into account long-term unintended consequences on the whole social-ecological system. In a recent evaluation of the World Bank's portfolio of climate change adaptation programs, the Independent Evaluation Group (IEG) warned of the need to do no harm to long-term resilience through short-sighted inventions taken in the name of climate change adaptation (IEG, 2012). The IEG warns that "well-meaning efforts to cope with today's climate variability can backfire in the longer run. Planting exotic trees in China's Loess Plateau, for instance, succeeded in boosting farmers' incomes and reducing terrible erosion problems – but is now recognized as having drawn down scarce groundwater" (IEG, 2012).

In a recent study in the Sunderbans of West Bengal, India, the World Bank found that many well-intentioned and supposedly adaptive activities in fact were maladaptive, and actually increased long-term vulnerability to climate change. For example, the seemingly protective 3,500 kilometer system of embankments, dating to the nineteenth century, constrict tidal flows through this vast, seasonally-flooded area, and the flows then erode the foundations of the embankments. Rising sea levels put additional further pressure on the embankments, and attempts to reinforce them make them heavier and less stable, so that when hit by storm surges they fail, flooding vast areas. The Bank's analysis recommended a multigenerational, managed retreat from flood-prone farmland. Embankments would be moved back, and mangroves restored on the flood-prone land, essentially letting natural biodiversity restore the ecosystem service of flood control that the embankments tried to provide through built infrastructure.

Some governments and donors are now promoting irrigation projects, both large and small, as, at least in part, climate change adaptation, whether or not there are trends or predictions of decreasing precipitation and water availabiliity. In many places the predictive ability of climate models is so poor that it is not possible to predict whether precipitation will be less or greater, so some governments and donors argue that irrigation is a "no regrets" strategy for the years when there will be less water for growing crops. In many climate predictions the variability of precipitation increases – such as in Malawi according to the Malawi Vulnerability Assessment recently conducted by the ARCC Project (ARCC, 2013) –leading some to make the argument for expanding irrigation to carry farmers through dry years.

The World Bank has used that justification in some cases, but their Independent Evaluation Group has pointed out the potentially maladaptive nature of such projects: "Expansion of irrigation is a potentially important avenue of adaptation, via expansion into rainfed areas, and through provision of increased storage where rainfall is becoming more variable…. It is plausible that sustainable land and water management practices improve farm resilience against rainfall variability and drought, but there is also a possibility of maladaptation, and hydrological impacts are not being systematically assessed" (IEG, 2012, p. 45). The IEG also states that "Traditional approaches to irrigation efficiency—such as lining the irrigation canals to prevent leakage—can be maladaptive. In many places, water savings are devoted to expanded cropping, so that total water demand stays the same, or even increases. And the apparent water savings often come at the expense of groundwater depletion, since what was leakage to the irrigation operator is recharge from the viewpoint of the well owner" (IEG, 2012, p. 34).

6.0 NATURAL CONNECTIONS: EXAMPLE OF INTEGRATING ADAPTATION AND CONSERVATION

6.1 MANGROVES IN MOZAMBIQUE

Conserving and restoring mangroves provides both climate-change adaptation benefits and conserves biodiversity. Around the world, as countries try to come to grips with the threat posed by the rising sea levels and the increase in intensity of cyclones, floods, and other extreme weather events predicted by models of global climate change, there is much discussion of improving coastal infrastructure as an adaptation measure. Mangroves are a soft, living infrastructure – not concrete seawalls and floodgates, but "green infrastructure" created by these amazing, biologically-diverse ecosystems (Ellison, et al., 2012). The physical protection from cyclones, winds, waves, and storm surges provided by mangroves, and their ability to trap and hold sediment and thereby build land, are ecosystem services provided by these intertidal forests. A recent study in the Red River Delta of Vietnam showed that mangroves reduced waves to less than 20% of their heights on coasts with no mangroves. Residents of Mozambique's generally poor coastal villages are the first to suffer the effects of storm surges and flooding; they cannot afford "hard" infrastructure to protect their communities, but can benefit from mangrove conservation and restoration.

Mangrove restoration is being supported in communities near Angoche, in Nampula Province, by the USAID-funded WWF-Care Alliance Primeiras and Segundas Program. Although planting mangrove "droppers" – the already-sprouted dispersing seeds of these trees – is easy and effective for some species, the silvicultural science of how to restore each of the main species in its proper intertidal zone is not complete, and more pilot work on mangrove restoration is needed.

Mangroves provide another ecosystem service: the trees, and the highly organic mud in which they grow, store and sequester carbon from the atmosphere, and thus contribute to climate change mitigation (USAID-Mozambique, 2012).

Image 4. Healthy mangroves near Angoche, Nampula Province, Mozambique
Photo by B. Byers, 2012

Image 5. Mangrove restoration near Angoche, Nampula Province, Mozambique, supported by USAID through the CARE-WWF Alliance Primeiras and Segundas Program.
Photo by B. Byers, 2012

Image 6. Beach at Ilha dos Búzios, site of former village destroyed by Cyclone Jokwe, 2008, after the protective fringe of mangroves was destroyed by overharvesting.
Photo by B. Byers, 2012

Image 7. Beach in Inguri, a high-density, low-income residential area of Angoche, with the few remnant mangroves visible in upper right of photo. Inguri occupies a low-lying, sandy peninsula, and by some estimates almost 30,000 people live here, no higher than a few meters above sea level.
Photo by B. Byers, 2012

6.2 RESTORING WILDLIFE CORRIDORS AND WATERSHED FORESTS IN KENYA

Information collected during the 2011 Kenya Tropical Forests and Biodiversity Assessment (USAID-Kenya, 2011) provides a case study of how elements of adaptation for conservation, conservation for adaptation, and even climate change mitigation could be integrated in the same geographic location.

A recently-constructed highway "underpass" allows elephants from the lowlands near Lewa, a private wildlife conservancy, to safely move up to the forests that surround Mount Kenya. Maintaining the possibility for such altitudinal migration is one of the recommended actions for helping species adapt to climate change. In this case, it also appears that it is allowing gene flow between lowland and mountain elephants to occur, which may also preserve the possibility of adaptive evolution to climate change in these elephant populations. This is an example of adaptation for conservation.

Above the highway with the underpass lies an area whose altitude and rainfall make it suitable for growing wheat, and in this "wheat belt" most of the montane forest has been cleared for agriculture. This has resulted in soil erosion and changes in the hydrology of watersheds on the northeastern side of Mount Kenya. The government of Kenya, local communities, and private landowners are working together to restore one watershed in the area, adjacent to the elephant underpass. Restoring biodiverse forests on this side of Mount Kenya will contribute to conservation for adaptation by facilitating elephant movements. It will at the same time contribute to climate change adaptation in the human communities living downstream by restoring the hydrological ecosystem services that montane forests provide: preventing soil erosion, improving water quality, absorbing and slowing runoff, and making flow regimes more natural and even. USAID has been funding a program in the area that is propagating and planting native tree species to restore and rehabilitate watersheds, and also sequester carbon, thereby contributing to climate change mitigation as well as adaptation.

Image 8. Underpass under highway to allow elephants to move from the Lewa lowlands up to the mountain forests on Mount Kenya. Such elephant movement maintains gene flow between lowland and mountain populations of elephants.
Photo by B. Byers, 2011

Image 9. Former forest around Mt. Kenya is now the wheat belt, cutting off movement of elephants and other wildlife, and causing extensive soil erosion.
Photo by B. Byers, 2011

Image 10. Watershed rehabilitation and revegetation on northwest side of Mount Kenya (near wheat field, native tree nursery, and elephant underpass in other photos).
Photo by B. Byers, 2011

Image 11. Seedlings of the indigenous cedar (*Juniperus procera*) for restoration of native forest, Mt. Kenya. Photo by B. Byers, 2011

6.3 CONSERVATION AGRICULTURE AND FOREST REGENERATION IN MALAWI

An evaluation of USAID-Malawi's two biodiversity projects is now being completed, and one of the success stories that is emerging is a synergistic suite of activities including:

- improving agricultural yields from the same amount of land through skillful farming;
- allowing native woodlands to regenerate;
- conserving fuelwood through more efficient cookstoves; and
- planting trees as well as food crops on farms.

This simple suite of activities has the potential to stabilize the agricultural frontier in many of the border-zone villages around the protected areas of Malawi, and thus reduce the main threat to biodiversity there – the expansion of smallholder agriculture.

Image 12. Conservation agriculture with rotation of maize, soy, and groundnuts, and vetiver grass strips and mulching for soil and water conservation, in the border zone of the Nkhotakota Wildlife Reserve
Photo by B. Byers

One key part of this strategy is what the project implementers call "conservation agriculture." The fundamental elements of conservation agriculture are: minimum or no tillage, which prevents soil erosion; mulching with crop residues to control weeds and maintain soil moisture; crop rotation with legumes to maintain soil fertility; and, generally, the use of fertilizer inputs, small amounts of herbicides to control weeds, and sometimes hybrid seeds. These farming practices significantly increase yields and reduce labor on the same area of land, and thereby reduce pressure to clear new land for agriculture.

Image 13. Natural regeneration of woodland in the Mphalamando Village Forest Area
Photo by B. Byers

In some places the increased yields from conservation agriculture make it possible for some farmers to stop farming on less-productive land. When they do, thanks to the amazing resilience of miombo woodland trees, a native woodland often regenerates rapidly from roots and stumps on the fallowed land. Within a period of only a few years farmers or villages can have woodlots of native trees through natural regeneration, with no tree planting involved.

Image 14. Firewood from thinning of an on-farm woodlot established by natural regeneration of miombo woodland trees, border zone of Vwaza Marsh Wildlife Reserve.
Photo by B. Byers

Firewood is the main cooking fuel in Malawi, used by an estimated 97 percent of rural households. Measurements show that only about 10 percent of the energy in the wood gets transferred to the cooking pot using the traditional three-stone cooking fire. The USAID biodiversity projects have been introducing new, more fuel-efficient cookstove designs that channel the heat to the cooking pot more efficiently, and hold and maintain the fire better. These stoves are almost twice as efficient at converting wood energy to cooking heat as the three-stone fire – and thus use only about half the wood, taking pressure off of native forests and on-farm trees.

Image 15. Fuel-efficient brick and clay stove, Nkhamayamaji Village, in the border zone of Nyika National Park Photo by B. Byers

These USAID-funded biodiversity projects are also promoting the propagation and on-farm planting of fast growing non-native trees such as *Senna siamea*, which within a few years can be cut for poles and firewood.

Image 16. Village woodlot of *Senna siamea*, Kapatakafinye Village, in the border zone of Nyika National Park
Photo by B. Byers

Protection and regeneration of native woodland near villages protects watersheds and groundwater recharge areas, thereby improving water availability, which in turn has health and sanitation implications – as well as benefits for climate change adaptation and biodiversity conservation.

Image 17. Community water tap, Nantali Village, in the border zone of Mulanje Mountain Forest Reserve. Intake of the gravity-fed tap is on a stream inside the Forest Reserve above a neighboring village, which has allowed charcoal-makers to cut the trees in the reserve illegally. Nantali's water supply dam and intake is now threatened by floods and siltation from the deforested area upstream.
Photo by B. Byers

It is instructive to compare this suite of interventions undertaken for biodiversity conservation with those identified as "adaptive strategies" by the Malawi Vulnerability Assessment now being completed by the ARCC Project (ARCC, 2013). The assessment identified a number of adaptation activities and strategies that are now being employed or could be in the future, including:

- shifting to hybrid or hazard-resistant varieties
- changes in crops planted
- conservation tillage, box ridging, compost and manure use
- diversification (crops, non-agricultural activities [i.e., aquaculture])
- community management of forest reserves; afforestation

These adaptation activities overlap with conservation agriculture, natural woodland regeneration, and on-farm planting of fast-growing non-native trees, activities being promoted for biodiversisty conservation.

4.4 LINKING BIODIVERSITY, CLIMATE CHANGE ADAPTATION, AND CLIMATE CHANGE MITIGATION

In general, "adaptation activities build resilience to the unavoidable impacts of climate change," while "mitigation seeks to reduce the amount of greenhouse gases released into the atmosphere and to recapture greenhouse gases currently in the atmosphere and sequester them in ecosystems" (USAID, 2012a). While this study focuses on the links between climate change adaptation and biodiversity conservation, we found many examples that link biodiversity with both adaptation and mitigation. This is the case in each of the examples above; all illustrate "triple co-benefits" for biodiversity, climate change adaptation, and climate change mitigation.

Reducing the deforestation and degradation of mangroves, and/or their restoration, are adaptive actions that increase the resilience of coastal communities to climate change and the sea level rise it will cause. The physical protection from cyclones, winds, waves, and storm surges that mangrove provide, and their ability to trap and hold sediment and thereby build land, are ecosystem services that contribute to an ecosystem-based approach to adaptation. Mangrove trees, and the highly organic mud in which they grow, also sequester carbon from the atmosphere, thus mitigating greenhouse gas emissions from fossil fuels and other sources (USAID-Mozambique, 2012).

Restoring biodiverse native forests on Mount Kenya contributes to biodiversity conservation through enhancing wildlife corridors and movement, and also to climate change adaptation through restoring hydrological ecosystem services important to downstream communitites. Forest restoration also sequesters carbon, producing climate change mitigation benefits.

The suite of activities being promoted by USAID biodiversity projects in Malawi contributes to biodiversity conservation and to climate change mitigation, as described above. Conservation agriculture also increases on-farm soil carbon, a climate change mitigation benefit. Natural woodland regeneration and planting non-native trees sequesters carbon, also contributing to mitigation. Finally, fuel-efficient woodstoves are a renewable energy technology, and contribute in that way to climate change mitigation.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. There is an emerging consensus that assessments and programming for climate change adaptation and biodiversity conservation need to take into account three aspects of their interaction:

   - Climate change adaptation for biodiversity conservation;
   - The role of biodiversity conservation in societal adaptation to climate change; and
   - Avoiding harm to biodiversity through adaptation actions.

2. For at least a decade, conservation organizations have been developing frameworks and methods to assess the vulnerability of biodiversity to climate change and incorporate those considerations into conservation planning. Those frameworks combine conservation and climate science, and are relatively well-developed conceptually, but can be difficult to implement practically.

3. Biodiversity conservation for societal adaptation to climate change has received less attention than adaptation for conservation until recently, but this approach is now developing rapidly.

4. We found several good examples of conceptual frameworks for integrating climate change adaptation and biodiversity conservation that:

   - encompass both social and ecological systems,
   - treat both adaptation for conservation and conservation for adaptation,
   - explicitly address ecosystem-based approaches to adaptation, including conserving ecosystem services, and
   - apply the concept of resilience to both social and ecological systems.

5. The concept of resilience in SESs has so far been largely confined to research and discussion in the academic literature. Practical applications and methodologies based on the potentially-powerful concept of resilience of SESs to climate change are not well developed.

General Recommendations

International and national government agencies and non-governmental organizations involved in biodiversity conservation (e.g., CBD, IUCN, U.S. Fish & Wildlife Service, TNC, WWF) should:

1. Disseminate, test, refine, and promote the already well-developed concepts of adapting biodiversity conservation strategies to take climate change into account.

International and national government agencies a nongovernmental organizations involved in development and conservation (e.g., CBD, UNDP, World Bank, USAID, CARE, WWF) should:

1. Continue to develop the view that biodiversity is the foundation for sustainable human development and of resilience of social-ecological systems to climate change, rather than viewing biodiversity conservation as a special interest or "sector;"

2. Further develop, and expand the use of, relatively new assessment frameworks and methodologies that integrate climate change adaptation and biodiversity conservation as cross-cutting issues, and lead toward integrated programming that views ecosystem-based approaches to climate change adaptation as a critical component of all adaptation strategies; and

3. Develop appropriate information and practical guidance to introduce, define, and promote key terms and concepts within their organizations including: ecosystem services, ecosystem-based approaches to adaptation, social-ecological systems (SESs), and resilience in SESs. Such guidance documents should be widely disseminated internationally so that these concepts can be brought into the conceptual "toolboxes" of both development and conservation organizations as soon as possible. Practical, easy-to-understand guidelines are needed to make these concepts accessible to on-the-ground program designers and managers.

7.2 CONCLUSIONS AND RECOMMENDATIONS FOR USAID

Conclusions

1. USAID Tropical Forestry and Biodiversity (FAA 118-119) and Environmental Threats and Opportunities Assessments are supposed to address climate change as one of five direct threats to biodiversity (USAID, 2005a; 005b). Our analysis of recent USAID assessments shows that almost all mention the issue of climate change, and 70 percent mention climate change adaptation, but a minority refer to the most current and innovative approaches for doing so (see Annex E). For example, only about one-fourth of the assessments refer to the concept of resilience, and only one of 34 reports reviewed mentioned the concept of ecosystem-based approaches to climate change adaptation.

2. The near-absence of the key concept of ecosystem-based approaches to adaptation in Tropical Forestry and Biodiversity assessments and ETOAs done within the last five years indicates that the teams of USAID staff and consultants conducting these assessments are not familiar with it. This represents a major gap, and also an important opportunity. The best "proxy" for this concept in assessments is probably the extent to which they discuss "ecosystem services," since those are the basis for ecosystem-based adaptation. About 80 percent of the assessment report mentioned ecosystem services – sometimes without much real emphasis, however.

3. Creating synergies between biodiversity conservation and resilience to climate change requires that assessments for each incorporate elements of the other, and that project and program design take the information from each kind of assessment into consideration.

4. USAID is currently directed to allocate funding for biodiversity conservation, climate change adaptation, and climate change mitigation. Each of these funding streams has criteria that must be met in order for USAID missions and programs to attribute the funding to appropriate activities. These attribution requirements present challenges – and in some cases disincentives – for the kind of integrated approaches we recommend.

5. Activities and interventions that jointly benefit biodiversity, climate change adaptation, and climate change mitigation are quite common. FAA 118-119 and ETOA assessments, which are used to inform the design of USAID programs, should identify opportunities to achieve co-benefits through the same activities funded from more than one of the USAID funding strands or "pillars" (e.g., biodiversity, climate change adaptation, climate change mitigation).

Recommendations for USAID

USAID should:

1. Develop updated guidelines for FAA 118-119 analyses and ETOAs that:

    a. call attention to the best available information, frameworks, and methodologies for "adaptation for conservation," such as checklists of specific ways climate change can threaten species and ecosystems, and options for adjusting biodiversity conservation strategies to climate change;

    b. call attention to the best available information, frameworks, and methodologies for "conservation for adaptation," emphasizing ecosystem-based adaptation and strategies for building resilience in social-ecological systems; and

    c. encourage awareness of the need to "do no harm" to biodiversity through interventions proposed in the name of climate change adaptation.

The information in this report, including Annex E, provides an outline for developing such guidelines. Their development would require a participatory process similar to that used to produce current guidelines for these analyses (USAID, 2005b). It would involve staff from USAID Regional Bureaus and the E3 Bureau who guide and oversee FAA 118-119 assessments and ETOAs being conducted by USAID missions.

2. Develop guidelines for climate change vulnerability assessments and options analyses that make USAID staff and consultants conducting or overseeing them aware of the same three topics needed in biodiversity assessments, as above. Climate change vulnerability assessments and options analyses especially need to address the issue of ecosystem-based adaptation options, and consider the topics of ecosystem services and resilience of social-ecological systems.

3. Revise and strengthen its 2012 document ***Building Resilience to Recurrent Crisis*** (USAID, 2012b) by incorporating the ecological dimensions of resilience. The updated document, or a companion report, should discuss resilience in social-ecological systems (SESs), not only the social dimensions of resilience. The key roles of biodiversity, ecosystems, and

ecosystem services in maintaining the resilience of social-ecological systems in the face of climate change should be emphasized.

4. Write up and/or conduct a series of case studies of the co-benefits of activities that jointly support climate change adaptation, climate change mitigation, and biodiversity conservation. These could inform the design of future integrated projects and programs that combine funding from these three strands or "pillars" of USAID funding.

ANNEX A: REFERENCES CITED

ABCG: Africa Biodiversity Collaborative Group. 2011. A Review of Climate Change Adaptation Initiatives within the Africa Biodiversity Collaborative Group Members.

Allen, C.D., Macalady, A.K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D.D., Hogg, E.H. (Ted), Gonzalez, P., Fensham, R., Zhang, Z., Castro, J., Demidova, N., Lim, J.-H., Allard, G., Running, S.W., Semerci, A., Cobb, N., 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259, 660–684. http://www.sciencedirect.com/science/article/pii/S037811270900615X Accessed 29 Nov. 2012.

Anderies, John M., Brian H. Walker, and Ann P. Kinzig. 2006. Fifteen weddings and a funeral: case studies and resilience-based management. *Ecology and Society* **11**(1): 21. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art21/

ARCC. 2013. Malawi Vulnerability Assessment Results. PowerPoint presentation to USAID-Malawi, April 2013.

Ayres, M.P., Lombardero, M.J., 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Science of The Total Environment 262, 263–286. http://www.usgcrp.gov/usgcrp/Library/nationalassessment/forests/forests7.pdf Accessed 29 Nov. 2012.

Ban, Natalie, et al. 2013. A social-ecological approach to conservation planning: embedding social considerations. Frontiers in Ecology and the Environment, Vol. 11, Issue 4, pp. 194-202. http://www.esajournals.org/doi/abs/10.1890/110205

Beaumont, Linda J., Andrew Pitman, Sarah Perkins, Niklaus E. Zimmermann, Nigel G. Yoccoz, and Wilfried Thuiller. 2011. Impacts of climate change on the world's most exceptional ecoregions. http://www.pnas.org/content/108/6/2306.short Accessed 29 Nov. 2011.

Bellard, et al., 2012. Impacts of climate change on the future of biodiversity. Ecology Letters, (2012) 15: 365–377. http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2011.01736.x/pdf Accessed 29 Nov. 2012.

BEST: Berkeley Earth Surface Temperature. 2012. http://berkeleyearth.org/ Accessed 29 Nov. 2012.

Bertin, R. I. (2008) Plant phenology and distribution in relation to recent climate change. Journal of the Torrey Botanical Society, **135**, 126-146. http://www.bioone.org/doi/abs/10.3159/07-RP-035R.1

Byers, Bruce A. 2012. Defining Ecosystem Services and Designing Mechanisms for Their Conservation. Ecological Society of America presentation, 9 August 2012. http://www.brucebyersconsulting.com/wp-content/uploads/2012/08/Byers-ESA-Presentation-9Aug12.pdf

Cardinale, Bradley, et al. 2012. Biodiversity loss and its impact on humanity. Nature vol 486: 59-67, 7 June 2012. http://mahb.stanford.edu/wp-content/uploads/2012/06/Nature-2012-Cardinale.pdf

CARE. 2009. Mainstreaming Climate Change Adaptation: A Practioner's Handbook. CARE International in Vietnam. http://www.careclimatechange.org/files/adaptation/CARE_VN_Mainstreaming_Handbook.pdf Accessed 15 Nov. 2012.

CATHALAC: Centro del Agua del Trópico Humedo para America Latina y el Caribe. Potential Impacts of Climate Change on Biodiversity in Central America, Mexico, and the Dominican Republic. http://www.cathalac.org/en/publications/publication-news/climate-change/235-potential-impacts-of-climate-change-on-biodiversity Accessed 4 Dec. 2012.

CBD: Convention on Biological Diversity. 2006. Global Biodiversity Outlook 2. http://www.cbd.int/doc/gbo/gbo2/cbd-gbo2-en.pdf Accessed 15 Nov. 2012.

CBD: Convention on Biological Diversity. 2009a. Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. CBD

Technical Series No. 41. https://www.cbd.int/doc/publications/cbd-ts-41-en.pdf Accessed 13 Nov. 2012.

CBD: Convention on Biological Diversity. 2009b. Review of the Literature on the Links Between Biodiversity and Climate Change: Impacts, Adaptation and Mitigation. CBD Technical Series No. 42. http://www.unep-wcmc.org/medialibrary/2010/09/13/2f278986/CBD_42.pdf Accessed 15 Nov. 2012.

CBD: Convention on Biological Diversity. 2009c. Forest Resilience, Biodiversity, and Climate Change: A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems. CBD Technical Series No. 43. http://www.cbd.int/doc/publications/cbd-ts-43-en.pdf Accessed 13 Nov. 2012.

Chen, I.-C., Hill, J.K., Ohlemuller, R., Roy, D.B., Thomas, C.D., 2011. Rapid Range Shifts of Species Associated with High Levels of Climate Warming. Science 333, 1024–1026.

Cleland, E., Chuine, I., Menzel, A., Mooney, H., Schwartz, M., 2007. Shifting plant phenology in response to global change. Trends in Ecology & Evolution 22, 357–365.

Conservation International. 2012a. Vulnerability Assessments: ecosystem-based adaptation. http://www.conservation.org/learn/climate/solutions/adaptation/ecosystem-based/Pages/vulnerability_assessment.aspx Accessed 16 Nov. 2012

Conservation International. 2012b. Adaptation Policy Brief: Necessary Elements for Adaptation. United Nations Framework Convention on Climate Change, COP 18, Doha, Qatar, 2012. http://www.conservation.org/Documents/CI_adaptation_policy_brief_necessary_elements_unfccc.pdf Accessed 20 Nov. 2012.

Cottingham, K. L., B. L. Brown, and J. T. Lennon. 2001. Biodiversity may regulate the temporal variability of ecological systems. Ecology Letters 4: 72-85.

Cross, M. S., E. S. Zavaleta, D. Bachelet, M. L. Brooks, C. A. F. Enquist, E. Fleishman, L. J. Graumlich, C. R. Groves, L. Hannah, L. Hansen, G. Hayward, M. Koopman, J. J. Lawler, J. Malcolm, J. Nordgren, B. Petersen, E. L. Rowland, D. Scott, S. L. Shafer, M. R. Shaw, and G. M. Tabor. 2012. The Adaptation for Conservation Targets (ACT) Framework: A Tool for Incorporating Climate Change into Natural Resource Management. Environmental Management (2012) 50:341–351. http://www.kresge.org/sites/default/files/Climate-Change-Adaptation.pdf Accessed 26 Nov. 2012.

Davis, M.B., 2001. Range Shifts and Adaptive Responses to Quaternary Climate Change. Science 292, 673–679.

Ecological Society of America. 2012. Communicating Ecosystem Services: Communications Tools: Ecosystem Services Fact Sheet. http://www.esa.org/ecoservices/ Accessed 27 Dec. 2012.

Ehlers, A., B.Worm, and T. B. H Reusch. 2008. Importance of genetic diversity in eelgrass Zostera marina for its resilience to global warming. Marine Ecology-Progress Series, 355, 1-7. http://eprints.uni-kiel.de/2787/1/42_Ehlers_2008_ImportanceOfGeneticDiversity_Artzeit_pubid8945.pdf Accessed 3 Dec. 2012.

ELAN: Ecosystems and Livelihoods Adaptation Network. 2013. Ecosystems and rights-based adaptation. http://www.elanadapt.net/ecosystem-rights-based-adaptation

Ellison, Joanna, Jonathan Cook, Jason Rubens, and Monfifa Fu. 2012. Climate Change Vulnerability Assessment and Adaptation Planning for Mangrove Systems. Washington, DC: World Wildlife Fund (WWF).

EPA: Environmental Protection Agency. 1999. Considering Ecological Processes in Environmental Impact Assessments. http://www.epa.gov/compliance/resources/policies/nepa/ecological-processes-eia-pg.pdf Accessed 29 Nov. 2012.

FAO: Food and Agriculture Organization. 2012. Wildlife in a Changing Climate. FAO Forestry Paper 167. Edgar Kaeslin, Ian Redmond, and Nigel Dudley, Eds. FAO, Rome. http://www.fao.org/forestry/30143-0bb7fb87ece780936a2f55130c87caf46.pdf

Foden, W., Mace, G., Vié, J.-C., Angulo, A., Butchart, S., DeVantier, L., Dublin, H., Gutsche, A., Stuart, S. and Turak,

E. 2008. Species susceptibility to climate change impacts. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds). *The 2008 Review of The IUCN Red List of Threatened Species*. IUCN Gland, Switzerland. http://cmsdata.iucn.org/downloads/species_and_climate_change.pdf

Folke, Carl, Steve Carpenter, Brian Walker, Marten Scheffer, Thomas Elmqvist, Lance Gunderson, and C.S. Holling. 2004. Regime Shifts, Resilience, and Biodiversity in Ecosystem Management. Annu. Rev. Ecol. Evol. Syst. 2004. 35:557–81. http://www.annualreviews.org/doi/abs/10.1146/annurev.ecolsys.35.021103.105711?journalCode=ecolsys

Franco, A.M.A., Hill, J.K., Kitschke, C., Collingham, Y.C., Roy, D.B., Fox, R., Huntley, B., Thomas, C.D., 2006. Impacts of climate warming and habitat loss on extinctions at species' low-latitude range boundaries. Global Change Biology 12, 1545–1553.

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit. 2011. Adaptation to Climate Change: New findings, methods and solutions. http://www2.gtz.de/dokumente/bib-2011/giz2011-0159en-climate-change.pdf Accessed 16 Nov. 2012.

Guariguata, M.R., Cornelius, J.P., Locatelli, B., Forner, C., Sánchez-Azofeifa, G.A., 2008. Mitigation needs adaptation: Tropical forestry and climate change. Mitigation and Adaptation Strategies for Global Change 13, 793–808. http://hal.cirad.fr/docs/00/69/93/27/PDF/Guariguata_2008_Mitigation_needs_adaptation.pdf Accessed 27 Nov. 2012.

Hampe, A., and R.J. Petit. 2005. Conserving biodiversity under climate change: the rear edge matters. Ecology Letters 8, 461–467. http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2005.00739.x/abstract

Heller, N.E., Zavaleta, E.S., 2009. Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological Conservation 142, 14–32. http://people.ucsc.edu/~zavaleta/pubs/Heller%20and%20Zavaleta%202009_BiolCons09_climate.pdf Accessed 27 Nov. 2012.

Hickling, R., Roy, D.B., Hill, J.K., Fox, R., Thomas, C.D., 2006. The distributions of a wide range of taxonomic groups are expanding polewards. Global Change Biology 12, 450–455.

Holling, C.S. (1973). "Resilience and stability of ecological systems". *Annual Review of Ecology and Systematics* **4**: 1–23. doi:10.1146/annurev.es.04.110173.000245 Accessed 13 Nov. 2012.

Hooper, D. U., et al. 2000. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75:3-55

IEG: Independent Evaluation Group. 2012. Adapting to Climate Change: Assessing World Bank Group Experience. Phase III. http://ieg.worldbankgroup.org/content/ieg/en/home/reports/climate_change3.html Accessed 28 Nov. 2012.

IISD: International Institute for Sustainable Development. 2009. CRiSTAL: Community Based Risk Screening Tool - Adaptation and Livelihoods. User's Manual. Version 4.0, May 2009. http://www.iisd.org/cristaltool/documents/cristal-manual-english-aug2010.pdf Accessed 21 Nov. 2012.

IPCC: Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Synthesis Report. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm Accessed 30 Nov. 2012.

IUCN: International Union for the Conservation of Nature. 2009. Ecosystem-based Adaptation:

A natural response to climate change. Authors: A. Colls, N. Ash, and N. Ikkala. http://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf Accessed 15 Nov. 2012.

IUCN: International Union for the Conservation of Nature. 2010. Building Resilience to Climate Change: Ecosystem-based adaptation and lessons from the field. Andrade Pérez, A., B. Herrera Fernandez, and R. Cazzolla Gatti, (eds.) Gland, Switzerland: IUCN. http://data.iucn.org/dbtw-wpd/edocs/2010-050.pdf Accessed

16 Nov. 2012.

IUCN: International Union for the Conservation of Nature. 2011. Why is biodiversity in crisis? http://www.iucn.org/what/tpas/biodiversity/about/biodiversity_crisis/?gclid=CMTit6nX0bMCFa5QOgoduh4Azw Accessed 15 Nov. 2012.

Kliejunas, John T. 2011. A Risk Assessment of Climate Change and the Impact of Forest Diseases on Forest Ecosystems in the Western United States and Canada. United States Department of Agriculture Forest Service, Pacific Southwest Research Station. General Technical Report PSW-GTR-236. December 2011. http://www.fs.fed.us/psw/publications/documents/psw_gtr236/psw_gtr236.pdf Accessed 15 Nov. 2012.

Knight, A.T., Smith, R.J., Cowling, R.M., Desmet, P.G., Faith, D.P., Ferrier, S., Gelderblom, C.M., Grantham, H., Lombard, A.T., Maze, K., Nel, J.L., Parrish, J.D., Pence, G.Q.K., Possingham, H.P., Reyers, B., Rouget, M., Roux, D., Wilson, K.A., 2007. Improving the Key Biodiversity Areas Approach for Effective Conservation Planning. BioScience 57, 256.

Lenoir, J., Gégout, J.-C., Guisan, A., Vittoz, P., Wohlgemuth, T., Zimmermann, N.E., Dullinger, S., Pauli, H., Willner, W., and J.-C Svenning. 2010. Going against the flow: potential mechanisms for unexpected downslope range shifts in a warming climate. Ecography. 33: 295-303. http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0587.2010.06279.x/pdf

Liu, Y., Stanturf, J., Goodrick, S., 2010. Trends in global wildfire potential in a changing climate. Forest Ecology and Management 259, 685–697. http://www.srs.fs.usda.gov/pubs/36444 Accessed 29 Nov. 2012.

Martin, Shaun. 2011. Ecosystem-based Adaptation: What Does It Really Mean? WWF ClimatePrep website. http://www.climateprep.org/2011/03/02/ecosystem-based-adaptation-what-does-it-really-mean/

Millar, C.I., Stephenson, N.L., Stephens, S.L., 2007. Climate Change and Forests of the Future: Managing in the Face of Uncertainty. Ecological Applications 17, 2145–2151. http://www.fs.fed.us/psw/publications/millar/psw_2007_millar029.pdf Accessed 27 Nov. 2012.

Mitton, J.B., and S.M. Ferrenberg. 2012. Mountain Pine Beetle Develops an Unprecedented Summer Generation in Response to Climate Warming. The American Naturalist, Vol. 179, No. 5 (May 2012), pp. E163-171. http://www.jstor.org/stable/pdfplus/10.1086/665007.pdf?acceptTC=true

Naeem, S., D. E. Bunker, A. Hector, M. Loreau, and C. Perrings, editors. 2009. Biodiversiy, ecosystem functioning, and human wellbeing: an ecological and economic perspective. Oxford University Press, New York.

National Wildlife Federation. 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation. Glick, P., B.A. Stein, and N.A. Edelson, editors. Washington, D.C. http://www.nwf.org/~/media/PDFs/Global-Warming/Climate-Smart-Conservation/NWFScanningtheConservationHorizonFINAL92311.pdf?dmc=1&ts=20121126T1041203989 Accessed 26 Nov. 2012.

Noon, B. R., L. L. Bailey, T. D. Sisk, and K. S. McKelvey. 2012. Efficient species-level monitoring at the landscape scale. Conservation Biology 26; 432-441.

Noss, R.F., 2001. Beyond Kyoto: Forest Management in a Time of Rapid Climate Change. Conservation Biology 15, 578–590. http://noss.cos.ucf.edu/papers/Noss%202001%20climate.pdf Accessed 27 Nov. 2012.

Ostrom, Elinor. 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325:419-422. http://vw.slis.indiana.edu/talks-fall09/Lin.pdf

Parmesan, C., 2006. Ecological and Evolutionary Responses to Recent Climate Change. Annual Review of Ecology, Evolution, and Systematics 37, 637–669.

Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J., Tammaru, T., Tennent, W.J., Thomas, J.A., Warren, M., 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature 399, 579–583.

Parmesan, C., Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421, 37–42.

Peterson, A.T., Stewart, A., Mohamed, K.I., Araújo, M.B., 2008. Shifting Global Invasive Potential of European Plants with Climate Change. PLoS ONE 3, e2441.

Peterson, Garry, Craig R. Allen, and C.S. Holling. 1998. Ecological Resilience, Biodiversity, and Scale. Nebraska Cooperative Fish & Wildlife Research Unit -- Staff Publications. Paper 4. http://digitalcommons.unl.edu/ncfwrustaff/4 Accessed 28 Nov. 2012.

Pierce, D.W., Barnett, T.P., Santer, B.D., Gleckler, P.J., 2009. Selecting global climate models for regional climate change studies. Proceedings of the National Academy of Sciences. http://www.pnas.org/content/106/21/8441.abstract Accessed 29 Nov. 2012.

Rader, R., Reilly, J., Bartomeus, J. ,and Winfree, R. 32013. Native bees buffer the negative impact of climate warming on honey bee pollination of watermelon crops. Global Change Biology. doi: 10.1111/gcb.12264

Raxworthy, C.J., Pearson, R.G., Rabibisoa, N., Rakotondrazafy, A.M., Ramanamanjato, J.-B., Raselimanana, A.P., Wu, S., Nussbaum, R.A., Stone, D.A., 2008. Extinction vulnerability of tropical montane endemism from warming and upslope displacement: a preliminary appraisal for the highest massif in Madagascar. Global Change Biology 14, 1703–1720.

Spittlehouse, D.L., and R.B Steward. 2003. Adaptation to climate change in forest management. BC Journal of Ecosystems Management 7–17. http://www.forrex.org/sites/default/files/publications/jem_archive/ISS21/vol4_no1_art1.pdf Accessed 27 Nov. 2012.

Sturrock, R.N., Frankel, S.J., Brown, A.V., Hennon, P.E., Kliejunas, J.T., Lewis, K.J., Worrall, J.J., Woods, A.J., 2011. Climate change and forest diseases. Plant Pathology 60, 133–149. http://www.fs.fed.us/wwetac/publications/Sturrock.PlantPath.2011.pdf Accessed 29 Nov. 2012.

Thomas, C., Franco, A., Hill, J., 2006. Range retractions and extinction in the face of climate warming. Trends in Ecology & Evolution 21, 415–416.

Tilman, David, and John A. Downing. 1994. Biodiversity and stability in grasslands. Nature 367: 363-365 (27 January 1994); doi:10.1038/367363a0

TNC: The Nature Conservancy. 2009. Adapting to Climate Change: Ecosystem-Based Approaches for People and Nature. Authors: Trevor Sandwith and Irene Suarez. June 2009. http://conserveonline.org/workspaces/climateadaptation/documents/ecosystem-based-adaptation-0/documents/ecosystem-based-approaches-for-people-and-nature/@@view.html Accessed 29 Nov. 2012.

TNC: The Nature Conservancy. 2010. Climate Change and Conservation: A Primer for Assessing Impacts and Advancing Ecosystem-based Adaptation in The Nature Conservancy. Adaptation Working Group: Craig Groves, Mark Anderson, Carolyn Enquist, Evan Girvetz, Trevor Sandwith, Loring Schwarz, Rebecca Shaw. March 2010. http://conserveonline.org/workspaces/climateadaptation/documents/a-primer-for-assessing-impacts/documents/a-primer-for-assessing-impacts-and-advancing-eba/@@view.html Accessed 29 Nov. 2012.

UNDP: United Nations Development Program. 2010. Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance – A Stocktaking Report. Authors: A. Olhoff and C. Schaer. UNDP: New York. http://www.preventionweb.net/files/13122_UNDPStocktakingReportCCmainstreamin.pdf Accessed 21 Nov. 2012.

UNFCCC. 2002. Annotated guidelines for the preparation of national adaptation programmes of action. http://unfccc.int/files/cooperation_and_support/ldc/application/pdf/annguide.pdf Accessed 20 Nov. 2012.

UNFCCC. 2012a. Database on ecosystem-based approaches to adaptation.

http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/6227.php Accessed 15 Nov. 2012.

UNFCCC. 2012b. NAPAs Received by the Secretariat. http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php Accessed 29 Nov. 2012.

UNFCCC-SBSTA: Subsidiary Body for Scientific and Technological Advice. 2011. Ecosystem-based approaches to adaptation: compilation of information. http://unfccc.int/resource/docs/2011/sbsta/eng/inf08.pdf Accessed 15 Nov. 2012.

USAID. 2005a. Biodiversity Conservation: A Guide for USAID Staff and Partners. Sept. 2005 http://pdf.usaid.gov/pdf_docs/PNADE258.pdf

USAID. 2005b. Tropical Forestry and Biodiversity (FAA 118-119) Analyses: Lessons Learned and Best Practices from Recent USAID Experience. Sept. 2005 http://pdf.usaid.gov/pdf_docs/Pnade195.pdf

USAID. 2007. Adapting to Climate Variability and Change: A Guidance Manual for Development Planning. August 2007. http://pdf.usaid.gov/pdf_docs/PNADJ990.pdf

USAID. 2009. Adapting to Coastal Climate Change: A Guidebook for Development Planners.

May, 2009. http://www.crc.uri.edu/download/CoastalAdaptationGuide.pdf Accessed 20 Nov. 2012.

USAID. 2010. Climate Change and Biodiversity. Brief for Internal Use.

USAID. 2012a. Climate Change and Development: Clean Resilient Growth: USAID Climate Change and Development Strategy. January 2012. http://transition.usaid.gov/our_work/policy_planning_and_learning/documents/GCCS.pdf Accessed 19 Nov. 2012.

USAID, 2013a. USAID: Environment: Biodiversity. http://transition.usaid.gov/our_work/environment/biodiversity/index.html Accessed 6 November 2012.

USAID, 2013b. USAID's Definition of Biodiversity Programs. http://transition.usaid.gov/our_work/environment/biodiversity/code.html

USAID, 2012b. Building Resilience to Recurrent Crisis: USAID Policy and Program Guidance. December 2012. http://transition.usaid.gov/resilience/USAIDResiliencePolicyGuidanceDocument.pdf

USAID-Kenya. 2011. Kenya Tropical Forest and Biodiversity Assessment. http://www.brucebyersconsulting.com/wp-content/uploads/2011/11/Kenya-Tropical-Forest-and-Biodiversity-Assessment-Sept-2011.pdf Accessed 5 December 2012.

USAID-Mozambique. 2012. Mozambique Environmental Threats and Opportunities Assessement. December 2012. http://www.brucebyersconsulting.com/wp-content/uploads/2013/01/Mozambique-Environmental-Threats-and-Opportunities-Assessment-2012.pdf

USAID-Tanzania. 2012. Tanzania Environmental Threats and Opportunities Assessment. November 2012. http://www.brucebyersconsulting.com/wp-content/uploads/2013/01/Tanzania-Environmental-Threats-and-Opportunities-Assessment-2012.pdf

US Department of State. 2011. Standard Foreign Assistance Indicators. Economic Growth Indicators and Definitions list. http://www.state.gov/f/indicators/index.htm

Voice of America. 2011. Conference Pushes Sharing of Africa Climate Data. March 30, 2011. http://www.voanews.com/content/conference-pushes-sharing-of-africa-climate-data--119006534/157805.html

Walker, B., Holling, C. S., Carpenter, S. R., Kinzig, A. (2004). "Resilience, adaptability and transformability in social–

ecological systems". *Ecology and Society* **9** (2): 5. http://www.ecologyandsociety.org/vol9/iss2/art5/ Accessed 13 Nov. 2012.

Walker, B., and D. Salt. 2006. Resilience Thinking: Sustaining Ecosystems in a Changing World. Island Press, Washington D.C., USA.

WCS: Wildlife Conservation Society. 2011. Planning for species conservation in a time of climate change. Authors: Watson, J.E.M., M. Cross, E. Rowland, L.N. Joseph, M. Rao, and A. Seimon. In, J. Blanco and H. Kheradmand (Eds.), Climate Change Volume 3: Research and technology for climatechange adaptation and mitigation. InTech Publishers. http://cdn.intechopen.com/pdfs/18729/InTech-Planning_for_species_conservation_in_a_time_of_climate_change.pdf Accessed 16 Nov. 2012.

Williams, J.W., Jackson, S.T., Kutzbach, J.E., 2007. Projected distributions of novel and disappearing climates by 2100 AD. Proceedings of the National Academy of Sciences 104, 5738–5742. http://www.pnas.org/content/104/14/5738.abstract Accessed 29 Nov. 2012.

Wilson, R.J., Gutiérrez, D., Gutiérrez, J., Martínez, D., Agudo, R., Monserrat, V.J., 2005. Changes to the elevational limits and extent of species ranges associated with climate change. Ecology Letters 8, 1138–1146.

Wilson, R.J., Gutiérrez, D., Gutiérrez, J., Monserrat, V.J., 2007. An elevational shift in butterfly species richness and composition accompanying recent climate change. Global Change Biology 13, 1873–1887.

WRI: World Resources Institute. 2011. Tools for Planning and Policymaking. Chapter 6 and Case Studies, pp. 90-105, in: World Resources Report 2010-2011: Decision Making in a Changing Climate—Adaptation Challenges and Choices. http://pdf.wri.org/world_resources_report_2010-2011.pdf Accessed 21 Nov. 2012.

WWF: World Wildlife Fund. 2003. Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. Editors: L.J. Hansen, J.L. Biringer, and J.R. Hoffmann. August 2003. http://wwf.panda.org/?8678/BUYING-TIME-A-Users-Manual-for-Building-Resistance-and-Resilience-to-Climate-Change-in-Natural-Systems Accessed 21 Nov. 2012.

ANNEX B: SCOPE OF WORK (SOW)

African and Latin American Resilience to Climate Change (ARCC)

USAID Contract Number AID-EPP-I-00-06-00008, AID-OAA-TO-11-00064

Title:	**Integrating Climate Change Adaptation into Biodiversity and Forestry Assessments and Programming**
Team:	Bruce Byers, Alison Cameron
Duration:	July 2012 – November 2012
Supervisor:	ARCC Supervisors: Matt Sommerville

BACKGROUND

The African and Latin American Resilience to Climate Change (ARCC) project represents an important vehicle for USAID to invest more effectually and consistently in adaptation programming and activities that support economic growth, democratic governance, health, human rights, and education. Tetra Tech ARD is implementing the African and Latin American Resilience to Climate Change (ARCC), a USAID/Washington D.C.-based PLACE IQC Task Order. ARCC will supply technical services for developing, testing, standardizing and replicating vulnerability assessment frameworks in order to assist USAID missions assess real climate change threats and their impacts on vulnerable populations and ecosystems, prepare adaptation strategies, and program critical USG funds for programs that address economic growth, especially the agriculture sector under the Feed the Future program. ARCC will build on climate adaptation resources that have been developed to bring improved science, methodologies and tools, and shared learning on adaptation into the mainstream of USAID and development partner programming. Four tasks comprise ARCC – developing vulnerability assessment methodologies; providing outreach, training and meeting support; developing and managing knowledge; and providing technical support to USAID missions.

Tetra Tech ARD will be assisted by partners ACDI/VOCA, the World Resources Institute, Cadmus Group, and Center for International Earth Science Information Network, Earth Institute, Columbia University.

OBJECTIVES

Development Challenge

Climate change is placing pressures on biodiversity and forests as species respond to new weather and atmospheric patterns. New distributional ranges for some species has led to disruption of ecosystems, and in some cases ecosystems are lost altogether, such as high altitudinal, shallow coral reefs and coastlines. As governments and conservation organizations assess threats, develop and implement strategies to protect biodiversity, climate change impacts must be considered, particularly considering that many of the species that are already vulnerable are particularly at risk from climate change impacts.

Biodiversity and habitat conservation professionals have only recently considered how best to respond to the new threat posed by climate change and there is a need for accessible background for development professionals to understand options for integrating climate change into assessments and program implementation. This will help development practitioners both understand the strengths and weaknesses of common tools used in projecting impacts on biodiversity, as well as the potential points for integration into implementation.

Global climate change (GCC) is a relatively new cross-cutting USAID priority and there is a need to integrate GCC into assessments and programming going forward, per the USAID Climate Change and Development Strategy 2012-2016. USAID Missions and Bureaus are required to undertake periodic Biodiversity and Forestry Analyses per the Foreign Assistance Act (FAA) Sections 118 and 119, and also frequently undertake Environmental Threats and Opportunities Assessments (ETOAs). These analyses are used when programming funds and developing country strategies in order to identify gaps, opportunities and recommendations within and outside the environment sector to conserve biodiversity and protect tropical forests. The analyses are to be considered in the USAID Country Development Cooperation Strategies (CDCS). USAID presently has clear guidance on performing 118/119 Assessments, and ETOAs. As climate change is increasingly identified as a threat that impacts biodiversity and forestry, there is a need to provide insight on how to consider climate change in these assessments (particularly considering that for the most part, the individuals who will undertake 118/119 assessments and ETOAs will not be climate change experts).

This SOW provides an opportunity to develop recommendations for effectively integrating climate change considerations into assessments and broader biodiversity and forestry programming. Broad advice will be complemented by USAID specific annex.

Purpose

The purpose of this Scope of Work (SOW) is to outline the impacts of climate change on biodiversity and forestry and consider how climate change (and climate data) can be considered in analyses and programming for biodiversity and forestry. The target audience for this work is development practitioners who assess threats to biodiversity and forestry and develop and implemented associated activities. Specific advice will be targeted to USAID and its partners.

The report should consider how to consider climate change science and projected climate impacts into biodiversity and forestry threats analysis and how to best to integrate adaptation into subsequent assessments, as a cross-cutting integrated theme. While climate change mitigation is a concern of USAID, this assessment should focus on climate change adaptation. It should also provide recommendations on how to mainstream climate change adaptation into biodiversity and forestry development programming.

This will also be complemented by a complementary assessment in an Annex that describes the extent to which recent 118/119 Analyses have addressed climate change adaptation. The Annex will also provide recommendations on how adaptation to climate change can be integrated into carrying out and reporting on 118/119 Analysis.

The report should be complemented by a brief outline of opportunities for follow on work on the topic of climate change adaptation and biodiversity and forestry, as well as a series of power point slides that highlight the major conclusions.

METHODOLOGY

This is expected to be a desk-based assessment undertaken by consultants who have experience with USAID policy, particularly 118/119 Analysis and ETOAs, and with expertise in climate change adaptation, biodiversity and forestry.

DELIVERABLES

The expected outputs from this assignment include the following:

Deliverables:

1. Draft report outline for approval

2. A concise report on: "Integrating Climate Change Adaptation into Biodiversity and Forestry Assessments and Programming"

    a. An executive summary (less than 1000 words);

    b. Review of the impacts of climate change on biodiversity and forestry (short-term and long-term);

    c. Role of climate data in informing potential understanding of impacts and responses

    d. Assessment of interventions that could be used to address climate change adaptation concerns in the biodiversity and forestry sectors.

    e. Recommendations

3. An Annex on: Assessment of consideration of GCC adaptation in recent 118/119 Analyses and ETOAs; and analysis and recommendation on how GCC adaptation can be better integrated into 118/119 Analyses and ETOAs, including best practices to implementers carrying out the Analyses (including consideration of cross-sectoral linkages);

4. A brief outline for a "Proposed Programme of Work on Integrating GCC Adaptation into USAID Biodiversity and Forestry Activities."

5. Preparation of three to five powerpoint slides that summarize the main lessons of the report.

APPROVED CONSULTANTS & LEVEL OF EFFORT

The core assignment will take place between 15 July and 15 December. The team will be supervised by Matt Sommerville, and coordinate closely with other ARCC team members.

Bruce Byers (Independent Consultant): Biodiversity/Forestry/Climate Change Expert (Up to 30 Days)

Dr. Alison Cameron (Independent Consultant): Climate Change and Biodiversity Scientist (Up to 10 days LOE)

TIMELINE FOR DRAFTS, FINAL DELIVERABLES, AND REVIEW PROCESS

(Dates to be negotiated with consultant and USAID). Anticipate November 2012.

Finalize SOW and identify team	by 18 July 2012
Draft Outline	by 1 September (to USAID)
First Draft	by 31 October (sent to USAID)
Tetra Tech ARD production	15 November
USAID and Tetra Tech ARD revisions returned to consultant	
Final submission	3 weeks following comments
Slide presentation submitted	30 November

Communications and Outreach Plan

The initial audience of the report will be USAID, but will be made available to development practitioners as well. Messaging will be consistent with the USAID Climate Change and Development Strategy.

The proposed Programme of Work will be used internally by the ARCC project and USAID to prioritize the next step activities on biodiversity/forestry and climate change adaptation.

The slide presentation may be presented by the consultant, but may also be used by USAID to present at internal USAID activities.

ANNEX C: BIOGRAPHICAL SKETCHES OF THE STUDY TEAM

Dr. Bruce Byers: (Independent Consultant) Biodiversity/Forestry/Climate Change Specialist & Team Leader

Dr. Bruce Byers is a biodiversity conservation and natural resources management specialist with more than 30 years of professional experience in more than 30 countries. His work focuses at the interface of biodiversity conservation and sustainable development. Bruce provides technical assistance to government agencies, NGOs, and the private sector worldwide, carrying out assessments, analyses, and applied research to design effective strategies and programs in complex ecological and social contexts. His most recent work involves the integration of biodiversity conservation and climate change adaptation, and the design of mechanisms to conserve ecosystem services.

Dr. Alison Cameron: (Independent Consultant) Climate Change and Biodiversity Scientist

Dr. Alison Cameron works on the interface between conservation and development, and has a specialist interest in climate change. Alison was born in Kenya, has an undergraduate degree in Tropical Environmental Science from Aberdeen University, and M.Sc. in Conservation Biology from the University of Cape Town, South Africa. She received her Ph.D. in 2005 from the University of Leeds, based on research in Madagascar on butterfly biodiversity and conservation as a case study in planning for climate change. Dr. Cameron is currently a lecturer in "Climate Change Adaptation and Mitigation" at Queen's University Belfast, UK.

ANNEX D: COMPARISON OF CLIMATE CHANGE ASSESSMENT METHODOLOGIES OF A RANGE OF CONSERVATION AND DEVELOPMENT ORGANIZATIONS

Note: order of assessment methodologies in table reflects whether they are integrated frameworks or development or conservation only, not date or alphabetical by organization name (see key to cell shading on page 63):

Organization, **Date, Title**	**Social systems and/or ecosystems included in assessment framework?**	**"Needs" addressed in methodology:** 1) adaptation for conservation 2) conservation for adaptation 3) do no harm	**Ecosystem-based adaptation opportunities mentioned?**	**Resilience concept used?**
CBD, 2009a, Connecting Biodiversity and Climate Change Mitigation and Adaptation	Both social and ecological systems	1) and 2)	Yes, strong emphasis on this type of adaptation option	"resilience" mentioned 39 times, mainly of ecosystems
IEG (World Bank Group), 2012a, Adapting to Climate Change: Assessing World Bank Group Experience	Both social and ecological systems	1), 2), and 3)	No, but ecosystem services are mentioned	"resilience" used 121 times, but referring to social systems only
TNC, 2010, Climate Change and Conservation: A Primer for Assessing Impacts and Advancing Ecosystem-based Adaptation in The Nature Conservancy	Both social and ecological systems	1) and 2)	Yes, strong emphasis on this type of adaptation option	"resilience" used 39 times, both ecological and social dimensions recognized
UNFCCC, 2002, Annotated Guidelines for the Preparation of National Adaptation	Both social and ecological systems	1) and 2)	No, although recognition of ecosystem services is implied	"resilience" used 4 times, both ecological and social dimensions

Programmes of Action				recognized
USAID, 2009, Adapting to Coastal Climate Change: A Guidebook for Development Planners	Both social and ecological systems	1) and 2)	No, although ecosystem services concept is well-developed, ecosystem-based management discussed	“resilience” mentioned 32 times, both ecological and social dimensions recognized
WRI, 2011, Decision Making in a Changing Climate—Adaptation Challenges and Choices	Both social and ecological systems	1) and 2)	Yes, strong emphasis on this type of adaptation option	“resilience” used 39 times, , both ecological and social dimensions recognized
Food and Agriculture Organization (FAO), 2012 , Wildlife in a changing climate	Species and ecosystems only	1)	Mentioned once but no serious presentation; ecosystem services concept is well-developed	“resilience” mentioned 6 time, referring only to social dimensions only once
National Wildlife Federation, 2011, Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment	Species and ecosystems only	1)	Mentioned once	“resilience” mentioned 33 times, but referring to ecological systems only
WCS, 2012, Planning for Species Conservation in a Time of Climate Change	Species and ecosystems only	1)	No, although ecosystem services mentioned	No
WWF, 2003, Buying Time: A User’s Manual for Building Resistance and Resilience to Climate Change in Natural Systems	Species and ecosystems only	1) and 2)	No, although ecosystem services concept is well-developed	“resilience” used 96 times, but ecological dimensions only
CARE, 2009, Mainstreaming Change Adaptation: A Practioner’s Handbook	Social systems only	None of these	No	“resilience” used 13 times, but referring to social systems only

GIZ, 2009, [Integrating Climate Change Adaptation into Development Planning]	Mainly social systems, but ecosystems and biodiversity mentioned	1) and 3)	No	"resilience" used 8 times, but referring to social systems only
IISD, 2009, [CRiSTAL: Community Based Risk Screening Tool - Adaptation and Livelihoods. User's Manual]	Social systems only	None of these (although maladaptation discussed related to social systems only)	No, but ecosystem services for livelihood support are mentioned	"resilience" used 4 times, but apparently referring to social systems only
UNDP, 2010, [Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance – A Stocktaking Report]	Social systems only	None of these (although maladaptation discussed related to social systems only)	No	"resilience" used 1 time only
USAID, 2007, Adapting to Climate Variability and Change: A Guidance Manual for Development Planning	Social systems only	None of these	No	"resilience" used 5 times, but referring to social systems only

Key:

Integrated framework	Ecological only	Social only

ANNEX E: SUMMARY OF CLIMATE CHANGE ADAPTATION IN RECENT FAA 118-119 ASSESSMENTS AND ETOAS

Country	Dates of Analysis
Angola	2008.doc (4MB); 2008.pdf (3.3MB)
Botswana	2008.pdf (1MB);
Burundi	2010.pdf (5 MB);
Chad	2011.pdf (850KB);
DRC	2010.pdf (3 MB);
Ethiopia	2008.pdf (691 KB;)
Ghana	2011ETOA.pdf (3MB); 2011ETOA(annex).pdf (1.5MB);
Kenya	2011.pdf;
Liberia	2008.pdf (6 MB);
Madagascar	2008.pdf (5MB);
Mali	2008.pdf (1 MB);
Mozambique	2008.pdf (4 MB); 2012 ETOA.pdf (3 MB)
Namibia	2010.pdf (2 MB);
Niger	2008.pdf (489KB)
Nigeria	2008.pdf (3 MB);
Rwanda	2008.pdf (4MB)
Senegal	2008.pdf (1MB);
Tanzania	2008ETOA.pdf (2MB); 2012 ETOA.pdf (3MB)
Togo	2008.pdf (414 KB)
Uganda	2011.pdf (2MB); 2006.pdf (1.1MB); 2001.doc (1MB)
Zambia	2011 ETOA.pdf (3MB); 2011.pdf (1MB);

Our SOW says that Deliverable 3 will be "An Annex on: Assessment of consideration of GCC adaptation in recent 118/119 Analyses and ETOAs; and analysis and recommendation on how GCC adaptation can be better integrated into 118/119 Analyses and ETOAs, including best practices to implementers carrying out the Analyses (including consideration of cross-sectoral linkages)." In fulfillment of that deliverable, we present the analysis and recommendations in this annex.

The material in this annex, combined with information presented in the body of this report, could provide the foundation for updated "lessons learned and best practices" guidelines for the USAID staff and consultants who conduct such assessments. Producing such guidelines would require a participatory process involving USAID Regional and E3 Bureau staff who are involved in guiding Missions in FAA 118-119 assessments and ETOAs, similar to the process used to produce current guidelines for these analyses (USAID, 2005b).

Africa Bureau

From the list of Africa FAA 118-119s and ETOAs available at http://www.encapafrica.org/bioformatrix.htm 21 countries with FAA 118-119s or ETOAs that have been done since 2008 were selected (see table below with links preserved). In addition, two recently-completed ETOAs that were completed since August, 2012, for Tanzania and Mozambique, were included for comparison with the 2008 reports from these two countries. A keyword search was used in each report (mostly PDF documents) to find the following keywords or phrases: climate change, adaptation, vulnerability, ecosystem services, resilience, ecosystem-based adaptation and mitigation. Keyword searches searched body of text, not including table of contents, abbreviations lists, or annexes. The count may sometimes include these terms in section headings, document titles, and other similar text. Comparative counts in the table below should therefore be considered semi-quantitative and suggestive, not necessarily rigorously comparable. Averages and ranges of keyword/phrase counts are given in the bottom row of Table E-1.

Country & Assesement Date	Keywords						
	climate change	climate change adaptation	climate change vulnerability	ecosystem services	climate change resilience	ecosystem-based adaptation	climate change mitigation
Angola, 2008	No	no	No	No	No	No	No
Botswana, 2008	Yes, 11 times	No, but word "adapt" used in similar context 6 times	No	No	No	No	No
Burundi, 2010	Yes, 33 times	Yes, 18 times	Yes, 3 times	Yes, 4 times	No	No	Yes, 7 times
Chad, 2011	Yes, 9	Yes, 3 times	Yes, 2 times	No	No	No	No

	times						
DRC, 2010	Yes, 47 times	Yes, 14 times	Yes, 2 times	Yes, 7 times	No	No	Yes, 2 times
Ethiopia, 2008	No	No	No	Yes, 2 times	No	No	No
Ghana, 2011	Yes, 67 times	Yes, 14 times	Yes, 15 times	Yes, 8 times	Yes, 1 time	No	Yes, 1 time
Kenya, 2011	Yes, 22 times	Yes, 2 times	Yes, 1 time	Yes, 31 times	Yes, 5 times	No	No
Liberia, 2008	Yes, 46 times	Yes, 4 times	No	Yes, 4 times	No	No	Yes, 1 time
Madagascar, 2008	Yes, 26 times	Yes, 4 times	Yes, 2 times	Yes, 2 times	No	No	Yes, 1 time
Mali, 2008	Yes, 13 times	Yes, 2 times	No	No	No	No	No
Mozambique, 2008	Yes, 14 times	No	No	Yes, 4 times	No	No	No
Mozambique, 2012	Yes, 38 times	Yes, 18 times	Yes, 1 time	Yes, 27 times	Yes, 9 times	Yes, 4 times	Yes, 3 times
Namibia, 2010	Yes, 44 times	Yes, 2 times	Yes, 3 times	Yes, 2 times	No	No	Yes, 1 time
Niger, 2008	Yes, 6 times	No	No	No	No	No	No
Nigeria, 2008	Yes, 5 times	No	Yes, 2 times	Yes, 2 times	No	No	No
Rwanda, 2008	Yes, 18 times	Yes, 6 times	Yes, 1 time	Yes, 3 times	No	No	Yes, 2 times
Senegal, 2008	Yes, 10 times	No	No	No	No	No	No
Tanzania, 2008	Yes, 1 time	no	no	Yes, 1 time	no	No	No
Tanzania, 2012	Yes, 37 times	Yes, 13 times	Yes, 14 times	Yes, 45 times	Yes, 17 times	No	No
Togo, 2008	Yes, 5 times	No	No	No	No	No	No

Uganda, 2011	Yes, 49 times	Yes, 8 times	Yes, 1 time	Yes, 6 times	No	No	No
Zambia, 2011	Yes, 33 times	Yes, 1 time	Yes, 4 times	Yes, 5 times	Yes, 1 time	No	Yes, 3 times
N=23 Mean/ Range	 X=23 0-67	 X=5 0-18	 X=2.2 0-15	 X=6.6 0-45	 X=1.4 0-17	 ----	 X=0.9 0-7

Table E.1: Comparison of Keyword/phrase Searches, Africa Bureau

Summary: Africa Bureau

- "Climate change": almost all assessments mentioned climate change, only 2/23 did not. There was a dramatic range of emphasis, however ranging from no mentions to 67 times.
- [climate change] "adaptation": 15/23 assessments mentioned this issue, but almost 1/3 did not. Range was again striking, from no mentions to 18 times.
- "vulnerability" [to climate change]: 13/23 assessments, about 1/2, used this term. Again a striking range, from zero to 15 mentions of the word.
- "ecosystem services": 16/23 assessments used this phrase, but nearly 1/3 did not, a surprising number for a concept so central to biodiversity and forest conservation. Range was extreme, from zero to 45 uses.
- [climate change] resilience: 5/23 assessments used this term, while almost 80% did not, suggesting a limited contact with the mainly academic, but potentially very useful, literature on this topic. A striking range of use, from zero to 17 times.
- ecosystem-based [approaches to climate change adaptation]: only one use of this phrase in any assessment (USAID-Mozambique, 2012), indicating that some extremely important thinking frequently associated with this phrase has not made its way into USAID biodiversity and tropical forest assessments and ETOAs. This is a surprising finding, and a major gap. The best "proxy" for this concept in assessments is probably the extent to which they discuss "ecosystem services," which are the basis for ecosystem-based adaptation – 2/3 did mention ecosystem services.
- [climate change] mitigation: 9/23 assessments used this term, significantly fewer than for "adaptation." The average use of the word in these assessments was also much lower than for "adaptation." This seems like a surprising finding, given all the attention that has been placed on forests and carbon sequestration, REDD+, etc. This seems to indicate a major opportunity to better link/integrate climate change mitigation and biodiversity conservation in assessments and programming.

Latin America and Caribbean Bureau

From the list of Latin America and Caribbean Bureau FAA 118-119s available at
http://transition.usaid.gov/locations/latin_america_caribbean/environment/118_119.html

11 countries with FAA 118-119s that have been done since 2008 were selected (see below with links preserved). The same methods of keyword/phrase searching were used as for Africa mission reports.

FAA 118/119 Country Analyses:

Bolivia - 10/2008, (PDF, 2660K)

Dominican Republic - 06/2011, (PDF, 1957K)

Ecuador- 06/2011, (PDF, 1500K)

Eastern_Caribbean - 2008 (PDF, 4320K)

Guatemala - 05/2010, (PDF, 4010K)

Guyana - 04/2008, (PDF, 2999K)

Honduras - 08/2009, (PDF, 1850K)

Jamaica - 2008, (PDF, 2440K)

Mexico - 2009, (PDF, 2070K)

Nicaragua - 01/2009, (PDF, 1403K)

Paraguay - 06/2010, (PDF, 1230K)

Country & Assesement Date	Keywords						
	climate change	climate change adaptation	climate change vulnerability	ecosystem services	climate change resilience	ecosystem-based adaptation	climate change mitigation
Bolivia, 2008	Yes, 58 times	Yes, 17 times	Yes, 2 times	Yes, 24 times	Yes, 1 time	No	Yes, 5 times
Dominican Republic, 2011	Yes, 51 times	Yes, 11 times	Yes, 9 times	Yes, 1 time	No	No	Yes, 4 times
Ecuador, 2011	Yes, 39 times	Yes, 4 times	No	Yes, 4 times	No	No	Yes, 5 times
Eastern Caribbean, 2008	Yes, 23 times	Yes, 5 times	Yes, 3 times	Yes, 10 times	Yes, 1 time	No	No
Guatemala, 2010	Yes, 7 times	Yes, 8 times	Yes, 9 times	Yes, 2 times	Yes, 5 times	No	Yes, 5 times

Guyana, 2008	Yes, 4 times	No	No	Yes, 4 times	No	No	No
Honduras, 2009	Yes, 10 times	Yes, 5 times	Yes, 2 times	Yes, 4 times	No	No	Yes, 1 time
Jamaica, 2008	Yes, 23 times	Yes, 4 times	Yes, 2 times	Yes, 3 times	No	No	Yes, 2 times
Mexico, 2009	Yes, 33 times	Yes, 3 times	No	Yes, 5 times	Yes, 1 time	No	Yes, 5 times
Nicaragua, 2009	Yes, 16 times	Yes, 1 time	Yes, 1 time	Yes, 20 times	No	No	Yes, 1 time
Paraguay, 2010	Yes, 9 times	No	No	Yes, 2 times	No	No	Yes, 1 time
N=11 Mean/ Range	X=25 4-58	X=5.3 0-17	X=2.5 0-9	X=7.2 1-24	X=0.6 0-5	----	X=2.6 0-5

Table E.2: Comparison of Keyword/phrase Searches, LAC Bureau

Summary: LAC Bureau

- "Climate change": all assessments mentioned climate change. There was a dramatic range of emphasis, however ranging from 4 to 58 mentions of the phrase.
- [climate change] "adaptation": 9/11 assessments mentioned this issue. Range was again striking, from no mentions to 17 times.
- "vulnerability" [to climate change]: 7/11 assessments, about 2/3, used this term. Range from zero to 9 mentions of the word.
- "ecosystem services": All 11 assessments used this phrase. Range was large, from 1 to 25 uses.
- [climate change] resilience: Only 4/11, about 1/3, of the assessments used this term, as for the Africa Bureau findings suggesting a limited contact with the mainly academic, but potentially very useful, literature on this topic.
- ecosystem-based [approaches to climate change adaptation]: no use of this phrase in any assessment, indicating that some extremely important thinking frequently associated with this phrase has not made its way into USAID biodiversity and tropical forest assessments and ETOAs. This is a surprising finding, and a major gap. The best "proxy" for this concept in assessments is probably the extent to which they discuss "ecosystem services," which are the basis for ecosystem-based adaptation – 2/3 did mention ecosystem services.
- [climate change] mitigation: 9/11 assessments used this term, the same number as for adaptation. As in Africa missions, however, the average use of the word in these

assessments was also much lower than for "adaptation." This seems like a surprising finding, given all the attention that has been placed on forests and carbon sequestration, REDD+, etc. Again, as in the Africa Bureau, this seems to indicate a major opportunity to better link/integrate climate change mitigation and biodiversity conservation in assessments and programming.

General Analysis of Recent USAID Assessments

This quick comparison using a simple keywords search provides some interesting results, in summary:

- Almost (but not quite) all of these assessments mentioned the issue of climate change (32/34).
- 70 percent of the reports mentioned the issue of climate change adaptation.
- About 60 percent of the reports (20/34) used the term "climate change vulnerability."
- Only about 1/4 of the reports (9/34) use the term or concept of "resilience." This suggests that in general the assessment teams working with USAID missions have limited knowledge of the mainly academic, but potentially very useful, literature on this topic.
- About 80 percent of the reports (27/34) used the term "ecosystem services." All LAC Bureau reports used it (11/11), while only about 2/3 of the Africa Bureau reports did (16/23). The range of uses of the term "ecosystem services" was extreme, from none (in 7/34 reports) to 45 times in one report, indicating a wide range in understanding and application of this concept. This is a somewhat surprising finding for a concept so central to biodiversity and forest conservation. Because understanding and applying the concept of ecosystem services is a key to designing "ecosystem-based approaches to adaptation," the absence of the concept in some reports, and lack of emphasis in others, seems to indicate that there is a need to improve the awareness and knowledge of USAID missions and assessment teams about it.
- Only one of the 34 reports (USAID-Mozambique, 2012) we reviewed used the phrase "ecosystem-based approaches to [climate change] adaptation." The near-absence of this key concept was an unexpected finding, and indicates that some extremely important and creative thinking associated with this phrase has not made its way into the mainstream of USAID biodiversity and tropical forest assessments and programming. This represents a major gap, and also an important opportunity. The best "proxy" for this concept in assessments is probably the extent to which they discuss "ecosystem services," since those are the basis for ecosystem-based adaptation. As noted above, about 80% of the reports mentioned ecosystem services, sometimes however without much real emphasis, so at least there is some basis for extending the concept from current benefits from ecosystem services to their role in adaptation to climate change.
- About half (18/34) of the reports mentioned the issue of climate change mitigation. Both the number of reports mentioning this topic, and the number of times the word was used in the reports, is lower for "mitigation" than for "adaptation." This was an unexpected finding, given the attention that has been placed on issues such as forests and carbon sequestration and REDD+ in recent years. In both the Africa and LAC Bureaus, this result seems to indicate a major opportunity to better link/integrate

climate change mitigation and biodiversity conservation in assessments and programming.

Recommendations for USAID

In order to develop recommendations about how climate change adaptation and biodiversity conservation can be better integrated in FAA 118-119 Assessments and ETOAs, and to identify "best practices" and guidelines for implementers carrying out these types of analyses, the study team recommends that USAID:

1. Convene a USAID working group or task force to advise on, and participate in, a more detailed and comprehensive comparative analysis of recent USAID FAA 118-119 and ETOA assessments that would identify "best practices" for integrating climate change adaptation and mitigation into these assessments, and generate guidelines for the Agency as a whole -- or at least some of its bureaus – about how to do so. This would process would be equivalent to that which produced the current guidelines (USAID, 2005b): ***Tropical Forestry and Biodiversity (FAA 118-119) Analyses: Lessons Learned and Best Practices from Recent USAID Experience***. Sept. 2005 http://pdf.usaid.gov/pdf_docs/Pnade195.pdf

2. Through the participatory process convened above, develop updated guidelines for FAA 118-119 analyses and ETOAs that:

    a. call attention to the best available information, frameworks, and methodologies for "adaptation for conservation," such as checklists of specific ways climate change can threaten species and ecosystems, and options for adjusting biodiversity conservation strategies for incorporation into the "actions needed" section of those analyses as relevant;

    b. call attention to the best available information, frameworks, and methodologies for "conservation for adaptation," emphasizing ecosystem-based adaptation and strategies for building resilience in social-ecological systems; and

    c. encourage awareness of the need to "do no harm" to biodiversity through interventions proposed in the name of climate change adaptation.

U.S. Agency for International Development

1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000 | Fax: (202) 216-3524
http://www.usaid.gov